

THE EXPECTATIONS HYPOTHESIS  
AND ITS POLICY IMPLICATIONS FOR AUSTRALIA

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## ABSTRACT

The expectations hypothesis has received considerable attention in the recent literature on inflation theory and policy. This is due partly to the fact that it provides an appealing explanation of the phenomenon of stagflation, the coexistence of high unemployment with accelerating inflation, and partly to the fact that it gives rise to the important distinction between the short-run and the long-run inflation-unemployment trade-off and to consequential challenging implications for the formulation of anti-inflation policy. Despite the attention which the hypothesis has received, the literature suffers from two notable deficiencies. The first is general, namely that there is nowhere in the literature a detailed theoretical analysis of the behavioural implications of the expectations hypothesis. The second deficiency is specific to the Australian literature, namely that there has been no research directed at examining the appropriateness of the expectations hypothesis (at least in its conventional form) for the Australian economy. One study has considered a modified form of the expectations hypothesis with reference to the Australian economy but that study has been shown to suffer from important methodological and empirical deficiencies such that little faith can be placed in its conclusions.

The two main aims of this thesis are related to the deficiencies of the literature just mentioned. The first main aim is to provide a complete and detailed theoretical analysis of the behavioural implications of the expectations hypothesis and, as a

corollary, to examine the relevance of these behavioural implications for the formulation of anti-inflation policy. The second aim is to determine empirically whether the expectations hypothesis can be considered appropriate for the Australian economy. The achievement of the latter aim is by no means straightforward, since the statistical and data problems involved are considerable.

An introduction to the thesis is presented in Chapter One. Four prototype models of the expectations hypothesis are specified in Chapter Two which also undertakes an examination of their behavioural implications and their implications for the formulation of anti-inflation policy. Thus, the first of the two main aims of the thesis is achieved in Chapter Two. A review of the empirical literature associated with the four prototype models is undertaken in Chapter Three. The problems inherent in a consideration of the appropriateness of these prototype models for the Australian economy are considered in Chapter Four and the approach to these problems to be adopted in the thesis is described. A description and critical assessment of the adequacy of the data used for the purposes of the econometric estimation of the parameters of the prototype models is given in Chapter Five. The results of these estimations of the structural parameters of various versions of the prototype models are presented in Chapter Six and a preferred estimation selected for each of the prototype models. This allows achievement of the second main aim of the thesis. It is found that none of the prototype models can be considered appropriate for the Australian economy on the basis of the specification of the models on which the estimates reported in Chapter Six are based, but that at least one of the



prototype models shows considerable promise. Finally, a number of ways in which the prototype models could be modified and extended are considered in Chapter Seven, which concludes with a number of suggestions for further work on the expectations hypothesis in the context of the Australian economy.

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## CHAPTER ONE

### INTRODUCTION

#### 1.1 Development of the Trade-Off Concept

Few would disagree with the statement that the goals of full employment and price stability are both highly desirable. Equally, however, it is now widely accepted that they are irreconcilable. Ultimately this can be attributed to the pioneering work of Phillips [109]. Phillips postulated that a stable relationship existed between the level of unemployment and the rate of change of money wage rates, a relationship which is now known universally as the "Phillips Curve". Phillips undertook the estimation of his relationship for the United Kingdom and used his results to determine the steady level of unemployment which would be associated with a stable price level. Using annual data for the period 1861 to 1913, Phillips obtained the following estimated relationship.

$$w_t = -0.900 + 9.638(u_t)^{-1.394} \quad (1.1)$$

where  $w$  denotes the percentage rate of change of money wage rates and  $u$  the unemployment rate (i.e. the level of unemployment expressed as a percentage of the labour force). To establish the value of  $u$  consistent with a stable price level Phillips assumed implicitly that the percentage rate of change of prices ( $p$ ) is linked to the percentage rate of change of money wage rates ( $w$ ) via a simple mark-up relationship of the form

$$p = w - q \quad (1.2)$$

where  $q$  denotes the percentage rate of change of productivity. On the assumption of an annual rate of productivity increase of 2 per cent, it follows from (1.1) and (1.2) that the unemployment rate consistent with a stable price level can be found by solving for  $u$  in

$$2.0 = -0.900 + 9.638(u)^{-1.394}$$

Proceeding in this way, Phillips found that the level of unemployment which would be associated with a stable price level in the United Kingdom was of the order of 2.5 per cent of the labour force, a level of unemployment far in excess of the level which is normally regarded as compatible with full employment in that country. Thus Phillips' results suggested quite strongly that the goals of full employment and price stability were incompatible at least as far as the United Kingdom was concerned.

A preliminary investigation of the Phillips curve for the United States, which was undertaken by Samuelson and Solow [113] shortly after the publication of Phillips' paper, confirmed the major implication of his findings. Samuelson and Solow found that, for the United States, the steady level of unemployment consistent with price stability was of the order of 5 to 6 per cent of the labour force<sup>1</sup> - an unemployment rate which is considerably in excess of the rate generally regarded as consistent with full employment in the United States.

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1. See [113, p. 192].

Once it became clear that the goals of full employment and price stability were irreconcilable it was natural to ask the question "How much additional unemployment is needed to reduce the rate of inflation by a specified amount?" This notion of a trade-off between inflation and unemployment first appears in Samuelson and Solow (although the term itself is not used by them). This is evidenced by the following passage in which they are concerned to show how the demand-pull and cost-push hypotheses could be distinguished empirically.

"If by deliberate policy one engineered a sizable reduction of demand or refused to permit the increase in demand that would be needed to preserve high employment, one would have an experiment that could hope to distinguish between the validity of the demand-pull and the cost-push theory as we would operationally reformulate those theories. If a small relaxation of demand were followed by great moderations in the march of wages and other costs so that the social cost of a stable price index turned out to be very small in terms of sacrificed high-level employment and output, then the demand-pull hypothesis would have received its most important confirmation. On the other hand, if mild demand repression checked cost and price increases not at all or only mildly, so that considerable unemployment would have to be engineered before the price level updrift could be prevented, then the cost-push hypothesis would have received its most important confirmation. If the outcome of this experience turned out to be in between these extreme cases - as we ourselves would rather expect - then an element of validity would have to be conceded to both views; and dull as it is to have to embrace eclectic theories, scholars who wished to be realistic would have to steel themselves to doing so." [113, p. 191]

Later they speak of a "... diagram showing the different levels of unemployment that would be 'needed' for each degree of price level change..." [113, p. 192] They also refer to the Phillips curve, interpreted in a wider sense than that conceived by Phillips as a

relationship between unemployment and the rate of inflation,<sup>2</sup> as a "menu for choice" [113, p. 193] and are probably the first to explicitly recognize that the policy implication of the irreconcilability of full employment and price stability is that "We shall probably have some price rise and some excess unemployment". [113, p. 193].

While Samuelson and Solow showed the way in adumbrating the notion of a trade-off between inflation and unemployment, the first serious attempt to measure the trade-off was made by Klein and Bodkin [64]. In addition, Klein and Bodkin appear to be the first authors to actually use the term "trade-off" in this context. Klein and Bodkin estimated a relationship of the following form using quarterly data for the period 1952 to 1959 for a selection of seven countries.

$$w_t = a_0 + a_1 u_t + a_2 p_t + a_3 t \quad (1.3)$$

Their results, which are of historic interest only, showed that  $a_1$  estimated negatively in six of the seven countries which they considered<sup>3</sup> and was significant in every case. The estimate of  $a_1$  was interpreted as an indicator of the severity of the trade-off

2. It is now common to refer to relationships between the rate of inflation (percentage rate of change of prices) and the level of unemployment, as well as those between the rate of wage inflation (percentage rate of change of money wage rates or costs) as "Phillips curves". This arises because given a traditional Phillips curve  $w = f(u)$ , a relationship between  $p$  and  $u$ ,  $p = f(u) - q$  can be found using the simple mark-up mechanism (1.1). In keeping with this terminology commonly used in the literature, the name Phillips curve will be used throughout this thesis to describe both  $w - u$  and  $p - u$  relationships.
3. The countries were Australia, Belgium, Canada, France, Italy, Japan and West Germany. Italy was the case in which the estimate of  $a_1$  was positive.

between unemployment and wage-inflation. Klein and Bodkin also undertook the exercise performed previously by both Phillips and Samuelson and Solow of calculating the steady level of unemployment consistent with price stability for each of the countries concerned. Their results broadly confirmed the conclusion of the earlier studies of Phillips and of Samuelson and Solow in that the level of unemployment consistent with price stability is likely to be far in excess of the full employment level.

The Phillips curve of Klein and Bodkin was very little different from that of its originator and the same is true of their trade-off concept. Both the Phillips curve and the trade-off concept were considerably refined by Perry [98]. A novel feature of Perry's work is that it is based, not on a single relationship between unemployment and the rate of wage-inflation, as in the case of Phillips, but on a family of such relationships. The role of shift parameter, defining individual members of this family of  $w - u$  relationships is played variously by profit rates, past changes in living costs and changes in profit rates. Using quarterly data for the United States over the period first quarter 1947 to third quarter 1960, Perry arrives at the following (preferred) estimated equation.

$$w_t = -4.313 + 0.367p_{t-1} + 14.711u_t^{-1} + 0.424R_{t-1} + 0.792(R_t - R_{t-1}) \quad (1.4)$$

where  $R_t$  denotes the profit rate. Using the mark-up relationship  $p_t = w_t - q_t$  to substitute for  $p_{t-1}$  in (1.4) and imposing a steady state by suppressing time subscripts, he then derives the following Phillips-type relationship.

$$w = -6.814 - 0.5797q + 23.24u^{-1} + 0.670R \quad (1.5)$$

This equation in fact defines a family of Phillips curves with  $q$  and  $R$  performing as the shift parameters. For example, assuming as Perry did, that the annual rate of productivity growth ( $q$ ) is 2.7 per cent, (1.5) reduces to

$$w = -8.379 + 23.24u^{-1} + 0.670R \quad (1.6)$$

which gives a family of Phillips curves, one for each value taken by  $R$ , the profit rate. Thus the trade-off concept implicit in Perry's work relates to the reduction in the rate of wage-inflation (and hence in the rate of inflation via the mark-up relationship) which can be achieved through a given increase in the level of unemployment, *provided that the shift parameters of (1.5), the rate of productivity increase ( $q$ ) and the profit rate ( $R$ ), remain constant.*

Perry's work is something of a landmark for two reasons. In the first place it explicitly recognized that the unemployment-wage-inflation relationship is not stable but rather that it shifts in a systematic way with changes in variables like profit rates and labour productivity. The second is that it carried an important implication for the formulation of anti-inflation policy. In Perry's words "While making the econometrician's job somewhat more difficult, this evidence that the wage relation is not fixed for all time makes the policy maker's problem somewhat easier. Not only does he have what freedom the present multivariate form of the relation offers, but also the possibility of shifting the whole relation in a desirable direction." [98, pp. 305-6]

The family of trade-offs found in Perry's work is fairly typical of the form to which the trade-off concept had evolved by the mid-sixties and, in particular, prior to the appearance of the

expectations hypothesis in the literature. The next major development of the trade-off concept arose out of the expectations hypothesis and, for this reason, it is appropriate to postpone further consideration of the development of the trade-off concept until the expectations hypothesis has been explained.

## 1.2 The Expectations Hypothesis

The expectations hypothesis is a model of the inflationary process which appears in its simplest form as a system of three simultaneous equations. The first of these describes a family of relationships between the unemployment rate (the level of unemployment expressed as a percentage of the labour force) and the rate of wage-inflation (the percentage rate of change of money wage rates, costs or earnings), the members of this family being distinguished by the associated value of the expected rate of inflation which plays the role of a shift parameter. This first equation will be described as the *wage equation*. In view of its specification, the wage equation is sometimes referred to in the literature as an "expectations augmented Phillips curve". Another description of the wage equation is as a "short-run Phillips curve", this title arising by virtue of the fact that each member of the family can be viewed as a Phillips curve applying only for as long as the corresponding expectation of the rate of inflation remains current. The second equation of the system which constitutes the expectations hypothesis will be referred to as the *expectations adjustment equation* or the *expectations formation equation* since it incorporates a hypothesis about the way in which expectations about the rate of inflation are revised in the light of the experience of the recent past. The third equation of



the system is a simple mark-up mechanism which serves as a link between the rate of wage-inflation and the rate of inflation. It will be referred to as the *price equation*.

A symbolic statement of the system of three equations just described which comprise the simplest form of the expectations hypothesis is the following.

$$w = f(u) + \delta p^e \quad 0 < \delta \leq 1 \quad (1.7)$$

$$\Delta p^e = \gamma(p - p^e) \quad 0 < \gamma \leq 1 \quad (1.8)$$

$$p = w - q \quad (1.9)$$

All the notation has been explained previously except  $p^e$  which denotes the expected rate of inflation.<sup>4</sup> A more formal statement of these relationships will be considered in Chapter Two. The above will suffice, however, for the moment. In addition, to certain other stipulations (which again will be considered in Chapter Two), two restrictions on the form of the function  $f(u)$  are required. These are  $f'(u) < 0$  and that there is some finite unemployment rate  $\bar{u}$  for which  $f(\bar{u}) = 0$ .

Central to the expectations hypothesis is the notion that prices rise because people expect them to rise. Although more careful consideration of its justification will be held over until Chapter Two, a simple statement of the propositions on which the expectations hypothesis rests is the following. People form an expectation about the rate of inflation and behave in a manner consistent with that expectation. In particular, wage-earners

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4. A standard notation is used throughout the thesis. A list of this notation appears as Appendix I.

attempt to obtain compensation for anticipated inflation through their wage bargains. Because employers also hold a similar inflationary expectation, they believe that increases in wage costs can be passed on to consumers in the form of higher prices and are therefore in a position to accede to the demands of wage-earners. In this way, there is a tendency for expected inflation to become realized. At the same time, wage-earners revise their inflationary expectations from one period to the next in the light of their experience of the actual rate of inflation. If the actual rate of inflation exceeds their expectation, the expected rate of inflation is revised upwards in the next period. Conversely, downward revision of inflationary expectations will occur if the actual rate of inflation falls short of the expectation formed for that period.

It is a straightforward matter to obtain an expression for the family of Phillips curves embodied in the expectations hypothesis as specified in (1.7), (1.8) and (1.9). Substituting (1.9) into (1.7) we get

$$p = f(u) - q + \delta p^e \quad (1.10)$$

or equivalently,

$$p = \phi(u) + \delta p^e \quad (1.11)$$

defining  $\phi(u)$  as  $f(u) - q$ . (1.11) is the family of Phillips curves referred to and, as mentioned above, they are often described as short-run Phillips curves to emphasize that each member of the family applies only for as long as the inflationary expectation to which it

corresponds is held. It has also been noted previously that  $p^e$ , the expected rate of inflation, is the shift parameter defining the members of this family. It follows from (1.11) that there is a trade-off between inflation and unemployment *in the short run*. The severity of this short-run trade-off is measured by  $\partial p / \partial u = \phi'(u) = f'(u)$  which is, of course, the common slope of the members of the family of short-run Phillips curves.

The question then arises as to whether or not there exists a trade-off between inflation and unemployment in the long-run or steady state. In the steady state all variables remain at constant levels and in particular  $p^e$  is constant or  $\Delta p^e$  is zero. Hence, from (1.8),  $p = p^e$  in the steady state. Using this equality in (1.11), it follows that in the long-run

$$p = \phi(u) + \delta p \quad (1.12)$$

When  $0 < \delta < 1$ , this implies that

$$p = \frac{1}{1 - \delta} \phi(u) \quad (1.13)$$

and when  $\delta = 1$ , that

$$\phi(u) = 0 \quad (1.14)$$

(1.13) and (1.14) characterize the long-run relationships between inflation and unemployment for the two cases  $0 < \delta < 1$  and  $\delta = 1$ . For the case,  $0 < \delta < 1$ , (1.13) defines the "long-run Phillips curve" and it follows from (1.13) that there is a long-run trade-off between inflation and unemployment. On the other hand, (1.14) shows that there is *no* long-run trade-off in the case for which  $\delta = 1$ .

In this case the long-run Phillips curve is degenerate - a vertical line passing through the unemployment rate  $u^*$ ,  $u^*$  being the solution to  $\phi(u) = 0$ . It will be shown in Chapter Two that the unemployment rate  $u^*$ , known as the natural rate of unemployment, is unique. Furthermore, since  $p$  does not enter (1.14), the natural rate of unemployment is consistent with any steady rate of inflation in the long-run.

The case  $\delta = 1$  corresponds to the situation in which wage-earners are fully compensated through the wage bargaining process for anticipated inflation. In this case the crucial consequence of the propositions on which the expectations hypothesis rests is that any trade-off between inflation and unemployment is only a temporary one, the long-run Phillips curve being a vertical line at the natural rate of unemployment. On the other hand, the case  $0 < \delta < 1$  corresponds to the situation in which wage-earners receive less than full compensation for anticipated inflation. In this case there is a trade-off between inflation and unemployment in the long-run as well as in the short-run.

At this point it is appropriate to return briefly to the development of the trade-off concept. One of the important features of the expectations hypothesis is that it gives rise to the important distinction between the short-run and the long-run trade-off between inflation and unemployment. This distinction is not found in the earlier literature through which the concept developed. In fact, the trade-off concept in the literature was always one of a long-run trade-off. Desai [18] argues forcefully that the original Phillips [109] curve is in fact a *long-run* Phillips curve. It is also clear by virtue of his imposition of a steady state that the

relationship from which Perry [98] obtains his estimate of the trade-off between inflation and unemployment (equation (1.6) here) embodies a long-run trade-off. Thus the expectations hypothesis is not only the origin of the distinction between the short-run and the long-run trade-off but is also the first place in which a genuine short-run trade-off appears.

### 1.3 Reasons for Interest in the Expectations Hypothesis

The expectations hypothesis has received considerable attention in the recent literature on inflation theory and policy. The main theoretical contributions are Friedman [30], Phelps [106], Lucas and Rapping [74] and Mortenson [79, 80]. There is also a sizeable literature of empirical studies associated with the expectations hypothesis. Among the more important studies are Solow [120], Parkin [89], Turnovsky and Wachter [134], Turnovsky [131], Toyoda [129], Vanderkamp [136] and Brechling [9]. Laidler [67] is an important contribution concerned with the implications of the expectations hypothesis for the formulation of anti-inflation policy.

One of the main reasons for this interest in the expectations hypothesis is that it provides an appealing explanation of the phenomenon of stagflation, the coexistence of high unemployment with accelerating inflation, which was the experience of most advanced Western economies during the early seventies. To illustrate this remark, consider the case in which  $\delta = 1$ . The family of short-run Phillips curves<sup>5</sup> and the vertical long-run Phillips curve (LRPC)

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5. The family of short-run Phillips curves referred to here is the set of  $p - u$  relationships (1.11). See above, p. 4n.

are shown in Figure 1.1 for this case. Suppose that the unemployment rate is steady at  $u_0$  and that, initially, the rate of inflation is  $p_0$ . At the initial position, the expected rate of inflation is zero because the current short-run Phillips curve is that corresponding to  $p^e = 0$ .<sup>6</sup> In view of the fact that the expected rate of inflation ( $p^e = 0$ ) falls short of the actual rate ( $p = p_0$ ), the expected rate will be revised upwards by virtue of (1.8). From (1.11), this produces an upward shift of the short-run Phillips curve. If the new expected rate of inflation is  $p_a$  then the short-run Phillips curve shifts to that marked  $p^e = p_a$ . With steady unemployment, the immediate effect of this shift is to raise the actual rate of inflation (via (1.11)) to  $p_1$ . Since the expected rate of inflation is  $p^e = p_a$ , the expected rate of inflation again falls short of the actual rate of inflation  $p_1$ . The result is another upward revision of expectations of the rate of inflation which in turn produces a further increase in the actual rate of inflation. The expected rate will again fall short of the actual rate of inflation and the resulting upward revision of expectations starts the cycle again. The result of this process is forever accelerating inflation with the unemployment rate steady at  $u_0$ . It will be shown in Chapter Two that this process is inevitable (given  $\delta = 1$ ) whenever the unemployment rate is smaller than the natural rate  $u^*$ . Given the presumption that  $u^*$  is a "high" unemployment rate the process of accelerating inflation just described represents an explanation of the phenomenon of

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6. Given that the long-run Phillips curve, the vertical line at  $u^*$ , is the locus of positions for which  $p = p^e$ , the expected rate of inflation to which any short-run Phillips curve corresponds can be read off as the vertical ordinate where the short-run Phillips curve in question intersects the long-run Phillips curve.

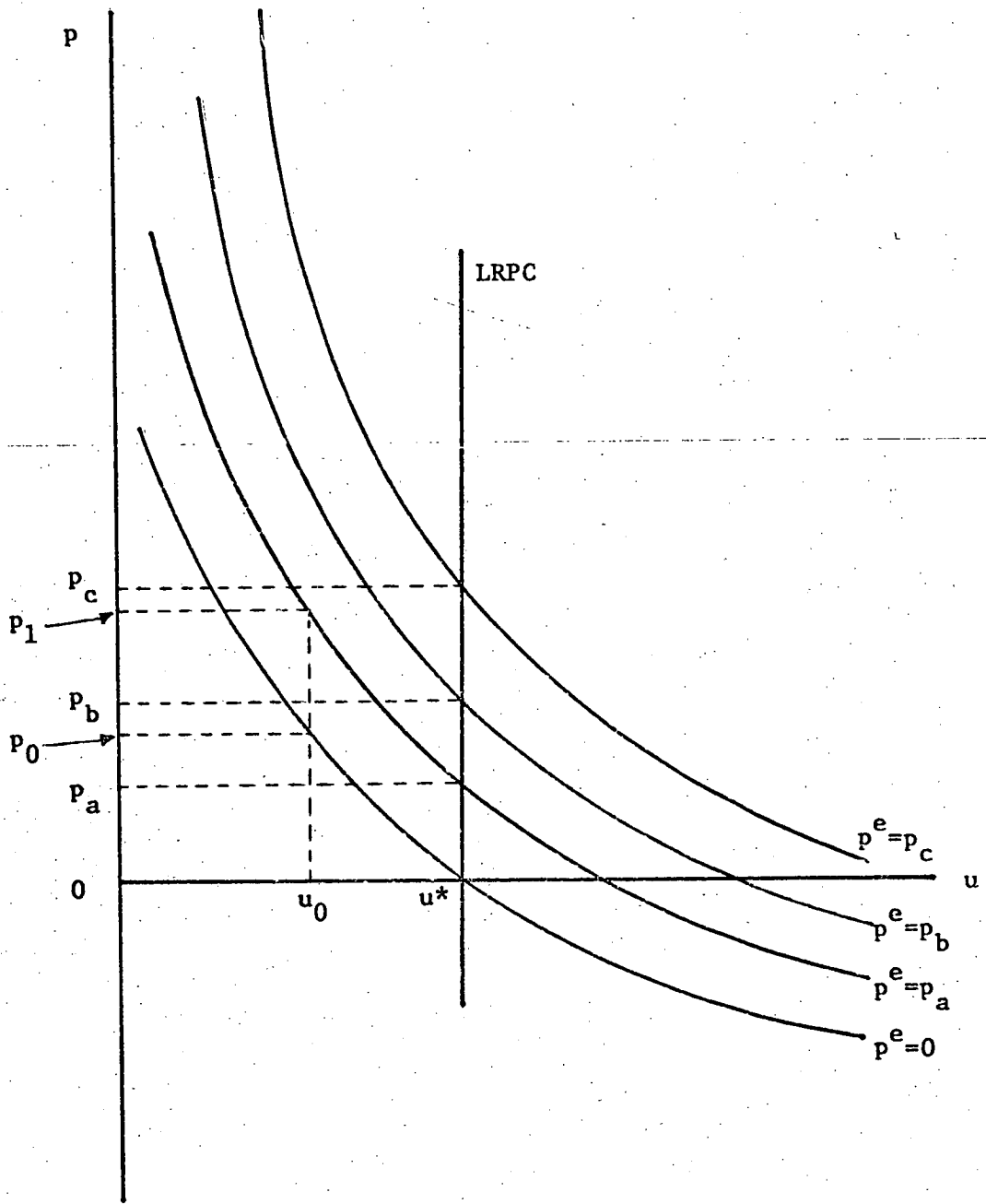


Figure 1.1

stagflation. An explanation along similar lines can also be provided for the case in which  $0 < \delta < 1$ .

A second reason for the expectations hypothesis being worthy of detailed consideration is that it raises important issues for the formulation of economic policy against inflation. These matters will again be considered carefully in Chapter Two but it is appropriate to note here that the expectations hypothesis presents the policy maker with a considerable number of alternative ways in which compatible unemployment-inflation rate combinations can be achieved. When  $\delta = 1$ , the long-run Phillips curve is a vertical line at  $u^*$ . Since the long-run Phillips curve represents the locus of unemployment-inflation rate combinations which are compatible in the long-run, this means that the  $\delta = 1$  case has little to offer the policy maker in the way of compatible combinations. He can in fact have any desired inflation rate but the natural rate is imposed upon him as the only unemployment rate consistent with steady inflation. On the other hand, the case  $0 < \delta < 1$  offers the policy maker considerable choice. In this case the long-run Phillips curve, and hence the locus of unemployment-inflation rate combinations which are compatible in the long-run, has a finite negative slope. The implication is that for each unemployment rate there is a unique rate of inflation which can be achieved as a steady rate in the long-run.

It follows from the preceding discussion that the value of  $\delta$  is of considerable importance with regard to the implications of the expectations hypothesis for the formulation of anti-inflation policy. In particular, it is important to know whether or not  $\delta$  equals unity and if it does, what the natural rate of unemployment is.



This question is thus far unresolved in the literature and the expectations hypothesis is worthy of continued attention for this reason alone.

#### 1.4 Aims and Outline of the Thesis

As was indicated in the previous section, the expectations hypothesis has received considerable attention in the recent literature on inflation theory and policy. It was pointed out that this is due partly to the fact that it provides an appealing explanation of stagflation, and partly to the fact that the expectations hypothesis gives rise to the important distinction between the short-run and the long-run inflation-unemployment trade-off and to consequential challenging implications for the formulation of anti-inflation policy. Despite the attention which the expectations hypothesis has received, the existing literature suffers from two notable deficiencies. The first is general, namely that there is nowhere in the literature a detailed theoretical analysis of the behavioural implications of the expectations hypothesis. Such discussion of the behavioural implications of the hypothesis as is given in the literature is universally both brief and sketchy. A typical treatment is that of Laidler [67, pp. 79-83]. The second deficiency is specific to the Australian literature, namely that there has been no research directed at examining the appropriateness of the expectations hypothesis (at least in its conventional form) for the Australian economy. In fact it would not be unreasonable to question whether an Australian expectations-hypothesis literature exists at all. To date only three contributions could be counted as comprising the Australian expectations-hypothesis literature.

One study (Parkin [91]) has considered a modified form of the expectations hypothesis with reference to the Australian economy. However, the other two contributions (a follow up study by Challen and Hagger [13] and a comment by Neville [83]) have shown that Parkin's study suffers from important methodological and empirical deficiencies and that little faith can be placed in its conclusions.

The two main aims of this thesis are related to the deficiencies of the literature just mentioned. The first is to provide a complete and detailed theoretical analysis of the behavioural implications of the expectations hypothesis and, as a corollary, to examine the relevance of these behavioural implications for the formulation of anti-inflation policy. The second aim is to determine empirically whether the expectations hypothesis can be considered appropriate for the Australian economy. The achievement of the latter aim is by no means straightforward, since the statistical and data problems involved are considerable.

The plan of the rest of the thesis is as follows. Four prototype models of the expectations hypothesis are set up in Chapter Two. The first two of these prototype models are in the spirit of the work of Friedman [30] in that the role of shift parameter in the wage equation is played by the expected rate of inflation. This pair of models differ one from the other only in that full compensation of wage-earners for anticipated inflation is embodied in the first while less than complete compensation for anticipated inflation is embodied in the second. The third and fourth prototype models are a full-compensation version and a less-than-full-compensation version of the expectations hypothesis in the form suggested by Phelps [106], the distinguishing feature of which is that the expected rate of

wage-inflation rather than the expected rate of inflation plays the part of shift parameter in the wage equation. The remainder of Chapter Two is occupied by an examination of the behavioural implications of each of the four prototype models and a consideration of their implications for the formulation of anti-inflation policy. Thus, the first of the two main aims of the thesis is achieved in Chapter Two.

The empirical literature associated with the prototype expectations hypothesis models is reviewed in Chapter Three. Notwithstanding the considerable empirical literature associated with expectational models, this review is a relatively limited one because only a small subset of the total literature is directly relevant to the *prototype* models of the expectations hypothesis specified in Chapter Two. The remainder of the literature is held over for consideration in the final chapter.

The problems inherent in determining the appropriateness of the prototype models for the Australian economy are identified in Chapter Four and a description of the approach to these problems adopted for the purposes of this thesis is presented. The major problem considered is the treatment of the expected rate of inflation and the expected rate of wage-inflation both of which are unobservable variables (at least in the sense of the usual meaning of "observable" in econometric work). Other problems discussed in Chapter Four are the specification of the expectations adjustment equation, the method of estimation of the structural parameters of the prototype models and the treatment of autocorrelation in the course of estimation. The latter problem is quite a difficult one arising out of the approach adopted to handle the expectations variables. It transpires that the

conventional methods of detecting autocorrelation are inapplicable in the context of the estimation of the prototype models and accordingly that a systematic procedure for detecting autocorrelation and for eliminating it once detected needs to be devised. Considerable effort is devoted to this task in Chapter Four.

A description of the data used for the purposes of the econometric estimation of the parameters of the prototype models and a critical assessment of the adequacy of that data is given in Chapter Five. The results of the estimation of the structural parameters of various versions of each of the four prototype models are presented in Chapter Six and a preferred estimation selected for each of the prototype models. This allows achievement of the second main aim of the thesis. It is found that while one of the prototype models shows considerable promise, none of them can be considered appropriate for the Australian economy on the basis of the specification of the models on which the estimates reported in Chapter Six are based. This fact notwithstanding the point estimates of the preferred prototype model are used to obtain an indication of the severity of Australia's short-run and long-run trade-offs between inflation and unemployment for the sample period. Taking the point estimates at face value they indicate that a long-run trade-off does indeed exist.

It is clear that some modification or extension of the prototype models is required in the case of the Australian economy. The ways in which the prototype models could be modified and extended are considered in Chapter Seven. In the course of this discussion that part of the empirical literature associated with the expectations hypothesis which is not covered in Chapter Three is treated. Chapter Seven concludes with a number of specific suggestions for further work on the expectations hypothesis in the context of the Australian economy.

## CHAPTER TWO

### PROTOTYPE MODELS OF THE EXPECTATIONS HYPOTHESIS

#### 2.1 Introduction

Although a number of different versions of the expectations hypothesis have appeared in the literature, they are sufficiently alike to enable the common features and the important points of difference to be identified. All versions of the expectations hypothesis are based on a wage equation in which the rate of change of money wages is said to depend upon the unemployment rate and upon expectations; and on a relationship which describes the way in which expectations are formed or adjusted. In some cases a price equation, linking the rate of change of money wages with the rate of change of prices, is also included. The major points of difference between the various versions of the expectations hypothesis concern the nature of the expectations which enter the wage equation (whether the variable in question is the expected rate of change of prices or the expected rate of change of money wages) and whether or not those expectations enter with a coefficient of unity.

The object of this chapter is to consider in detail four models which can be looked upon as prototype models of the expectations hypothesis, to present the theoretical basis for each of them and to develop their behavioural implications. The chapter concludes with a consideration of the implications of the prototype models of the expectations hypothesis for the formulation of anti-inflation policy.

A preoccupation of the literature in this area has been with the existence and severity of the short-run and long-run trade-offs between inflation and unemployment. These trade-offs will also be considered in the course of the discussion of the prototype models of the expectations hypothesis in the current chapter.

## 2.2 Prototype Model A.1

The first prototype model of the expectations hypothesis is essentially that which underlies Friedman [30]. The expectations which enter the wage equation of this model are of the rate of change of prices and their coefficient is unity. The model can be written

$$w = t(u) + p^e \quad (2.1)$$

$$\dot{p}^e = \gamma(p - p^e) \quad 0 < \gamma < 1 \quad (2.2)$$

$$p = w - q \quad (2.3)$$

For convenience the model is specified in continuous terms, i.e. all variables are regarded as continuous functions of time. The notation is as follows.

$w$  = percentage rate of change of money wage costs per man<sup>1</sup>  
(rate of wage-inflation)

$p$  = percentage rate of change of prices (inflation rate)

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1. Wage costs are interpreted here as those for which the employee is the recipient. They can alternatively be described as compensation per man. Thus, in addition to wages and salaries, items like paid leave, leave loadings, superannuation and meal allowances are expressly included while payroll tax is excluded.

$u$  = unemployment rate, i.e. unemployment expressed as a percentage of the labour force

$p^e$  = expected percentage rate of change of prices  
(expected inflation rate)

$q$  = percentage rate of change of output per man

A dot over a variable is used to denote its time derivative so that  $\dot{p}^e = dp^e/dt$  stands for the rate of change of the expected inflation rate and  $\dot{p} = dp/dt$  denotes the rate of change of the actual inflation rate.

When expectations of inflation are zero ( $p^e = 0$ ), (2.1) reduces to the Phillips curve<sup>2</sup>  $w = f(u)$ . Accordingly, to guarantee the conventional properties of the curve,  $f(u)$  needs to be subject to the restrictions  $f'(u) < 0$ ,  $f''(u) > 0$ ,  $0 = f(\bar{u})$  for some  $\bar{u} > 0$ ,  $\bar{u}$  being the unemployment intercept of the Phillips curve for  $p^e = 0$ .

Friedman argues<sup>3</sup> that the Phillips curve  $w = f(u)$  is relevant only in circumstances where prices and wages are stable, and furthermore are expected to be stable. In other words Friedman's view is that the Phillips curve is an hypothesis about the behaviour of real wages not money wages. If wage bargains were struck continuously a relationship with the rate of change of real wages as its dependent variable could be converted to one with the rate of change of money wages as its

2. The literature on the Phillips curve is an extensive one, the original contribution being Phillips [109]. A variety of possible theoretical justifications have been proposed. Of the early contributions those of Lipsey [71] and Corry and Laidler [15] are prominent. Among the recent contributions those which bear the title "the new microeconomics" have the most theoretical appeal. The most important work here is that of Phelps [106], Holt [52, 53], Mortensen [80] and Lucas and Rapping [74]. For a recent reappraisal see Desai [18].

3. Friedman [30], p. 8. See also Laidler [67], p. 79.

dependent variable by adding the current rate of inflation to the former. However, wage bargains are struck only at discrete intervals of time. At the time a given wage bargain is struck the relevant inflation rate which influences the behaviour of the parties to that bargain is not the current rate of inflation but the rate of inflation expected over the period for which the bargain is to be struck.<sup>4</sup>

Accordingly to convert the Phillips relationship whose dependent variable is the rate of change of real wages to one whose dependent variable is the rate of change of money wages, the expected rate of inflation has to be added to the former. The result of this procedure is the wage equation (2.1),  $w = f(u) + p^e$ .

The wage equation (2.1) can be viewed as a family of short-run Phillips curves each of which corresponds to a particular *expected* inflation rate. The members of the family are described as short-run because each applies only for as long as parties to the wage bargain hold the inflationary expectation to which it corresponds. Each member of the family describes the short-run trade-off between the rate of change of money wages and the unemployment rate given the current inflationary expectation. The coefficient of  $p^e$  in the wage equation (2.1) is postulated to be unity, the implication of which is that a one percentage point increase in  $p^e$  shifts the short-run Phillips curve upwards by the full one percentage point. It follows that the vertical distance between any two short-run Phillips curves, like those shown as  $SR_0$ ,  $SR_1$ ,  $SR_2$  in Figure 2.1<sup>5</sup> is just the difference

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4. Although, of course, the current rate of inflation as well as its behaviour in the recent past may influence the formation of expectations about the rate of inflation by the parties to the wage bargain.

5. See p. 24.



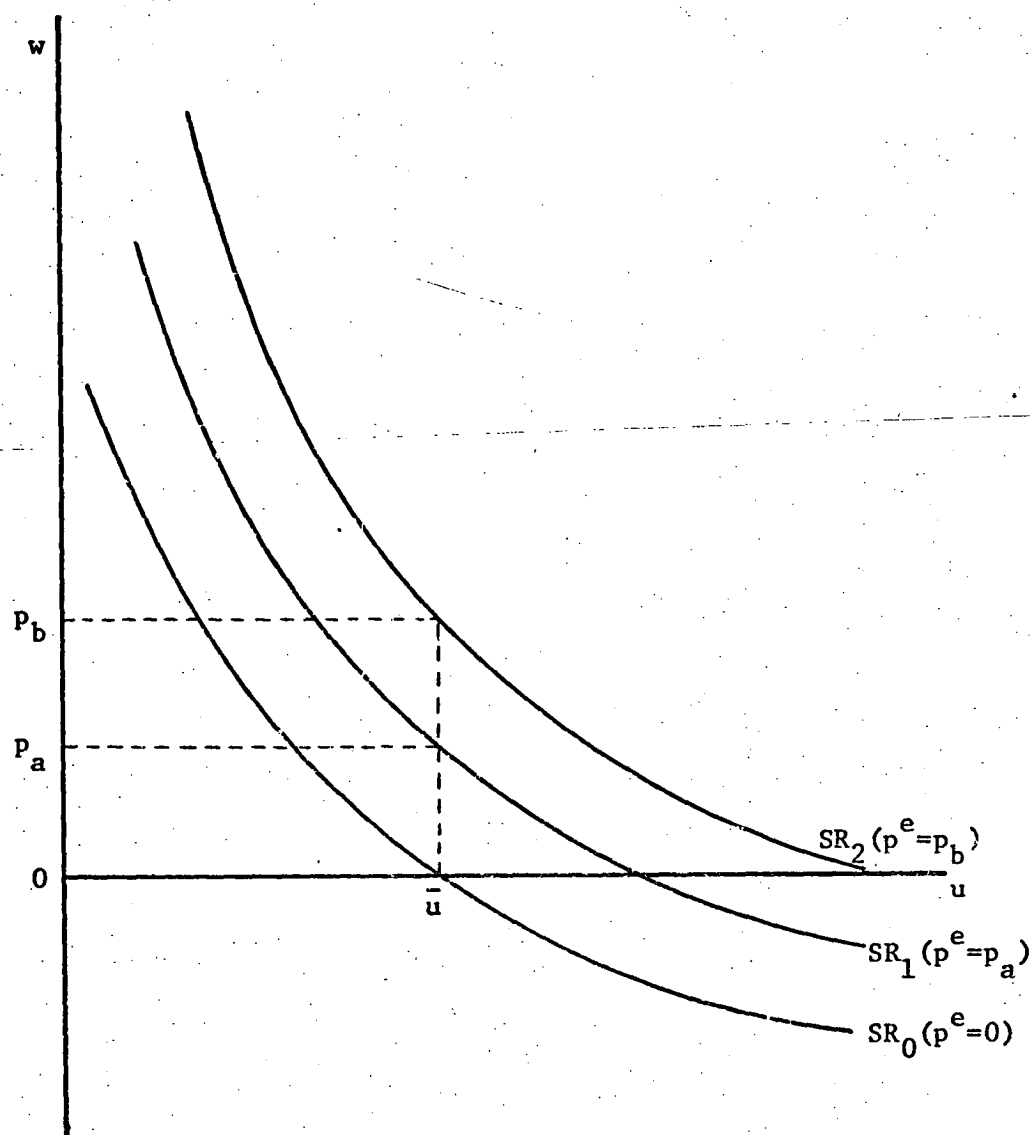


Figure 2.1

in the expected inflation rates to which the curves correspond. Equivalently, the  $p^e$  level to which a given short-run Phillips curve corresponds can be read off as the vertical ordinate for the curve in question at the unemployment rate  $u = \bar{u}$ .<sup>6</sup>

Equation (2.2) concerns the process by which inflationary expectations are revised or adjusted. Its form is the "adaptive expectations" hypothesis, first used by Cagan [10], in which expectations, when not realized, are corrected by a proportion  $\gamma$  of the error. When inflationary expectations are correct, in the sense of being realized, no revision takes place and last period's inflationary expectations are carried forward into the next period. It is well-known that the discrete statement of the adaptive expectations hypothesis is equivalent to making  $p^e$  an infinite geometric distributed lag of past actual inflation rates.

The remaining relationship of Model A.1, equation (2.3), is a simple mark-up price equation designed to provide a link between  $p$  and  $w$ . This particular form has been chosen for its extreme simplicity. From an analytical standpoint, however, there is nothing to be gained from a more complex price equation - the conclusions will not be any different qualitatively.<sup>7</sup>

An important behavioural implication of Model A.1 concerns the long-run trade-off between inflation and unemployment. Before going on to consider this matter, it is necessary to provide a careful interpretation of the term "long-run". The object of the

6. Because  $f(\bar{u}) = 0$ .

7. This is especially true if  $q$  is looked upon as a proxy for all non-wage influences on the inflation rate, rather than being interpreted strictly in accordance with its definition.

analysis of models like the one presently under consideration is to provide results that are of interest to policy-makers. Accordingly, the appropriate interpretation of the long-run is that which best conforms to the meaning a policy-maker would attach to the term. For this reason "long-run" will be interpreted in the sense of a steady state, that is, a situation in which all variables persist indefinitely at unchanging levels.<sup>8</sup> By "long-run" a policy maker would mean "a period long enough for the effects of a policy change<sup>9</sup> to be substantially achieved", which differs from the steady state concept only in that "substantially" replaces "fully".

An immediate implication of adopting the steady state interpretation of the long-run is that the long-run is also a state of expectation fulfilment. In the steady state,  $p = \bar{p}$  and  $p^e = \bar{p}^e$ , where the bar denotes a constant steady state value. Since  $p^e = \bar{p}^e$  is constant (by definition) in the steady state it follows that  $\dot{p}^e = 0$  and from (2.2) this requires that  $p = p^e$  or that  $\bar{p} = \bar{p}^e$ . In other words, expectations of the rate of inflation are realized in the long-run if the steady state interpretation is adopted and expectations are revised adaptively as in (2.2).

Having shown that  $p = p^e$  in the long-run, the long-run implications of the model can be obtained by making use of this equality. Substitution of (2.1) into (2.3) yields

$$p = f(u) + p^e - q \quad (2.4)$$

---

8. Remembering that in the present context, the "levels" of variables are rates of change in the case of  $p$ ,  $p^e$  and  $w$ .

9. In the present context, "policy change" means manipulation of the unemployment rate.

For algebraic convenience, define

$$\phi(u) = f(u) - q \quad (2.5)$$

so that (2.4) becomes

$$p = \phi(u) + p^e \quad (2.6)$$

An equivalent form of Model A.1 therefore comprises (2.6) and (2.2), the required restrictions on  $\phi(u)$  being<sup>10</sup>  $\phi'(u) < 0$ ,  $\phi''(u) > 0$ ,  $0 = \phi(u^*)$  for some  $u^* > 0$  where  $\phi(u^*) = f(u^*) - q$ .

It will be recalled from Chapter One that it is common to refer to  $p - u$  relationships as well as  $w - u$  relationships as Phillips curves and that, in conformity with the literature, this usage is adopted here. As such (2.6) defines a family of short-run Phillips curves of the  $p - u$  variety. Some members of this family are shown in Figure 2.2 as the curves marked  $SR'_0$ ,  $SR'_1$  and  $SR'_2$ . These curves are obtained from those comprising the family defined by (2.1) (some members of which were shown in Figure 2.1) by shifting the latter curves vertically downward by  $q$  points.

Using the long-run equality  $p = p^e$  in (2.6) produces

$$p = \phi(u) + p$$

That is, in the long-run

$$\phi(u) = 0 \quad (2.7)$$

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10. These restrictions are obtained from (2.5) and the restrictions placed on  $f(u)$  earlier. See above, p. 22.

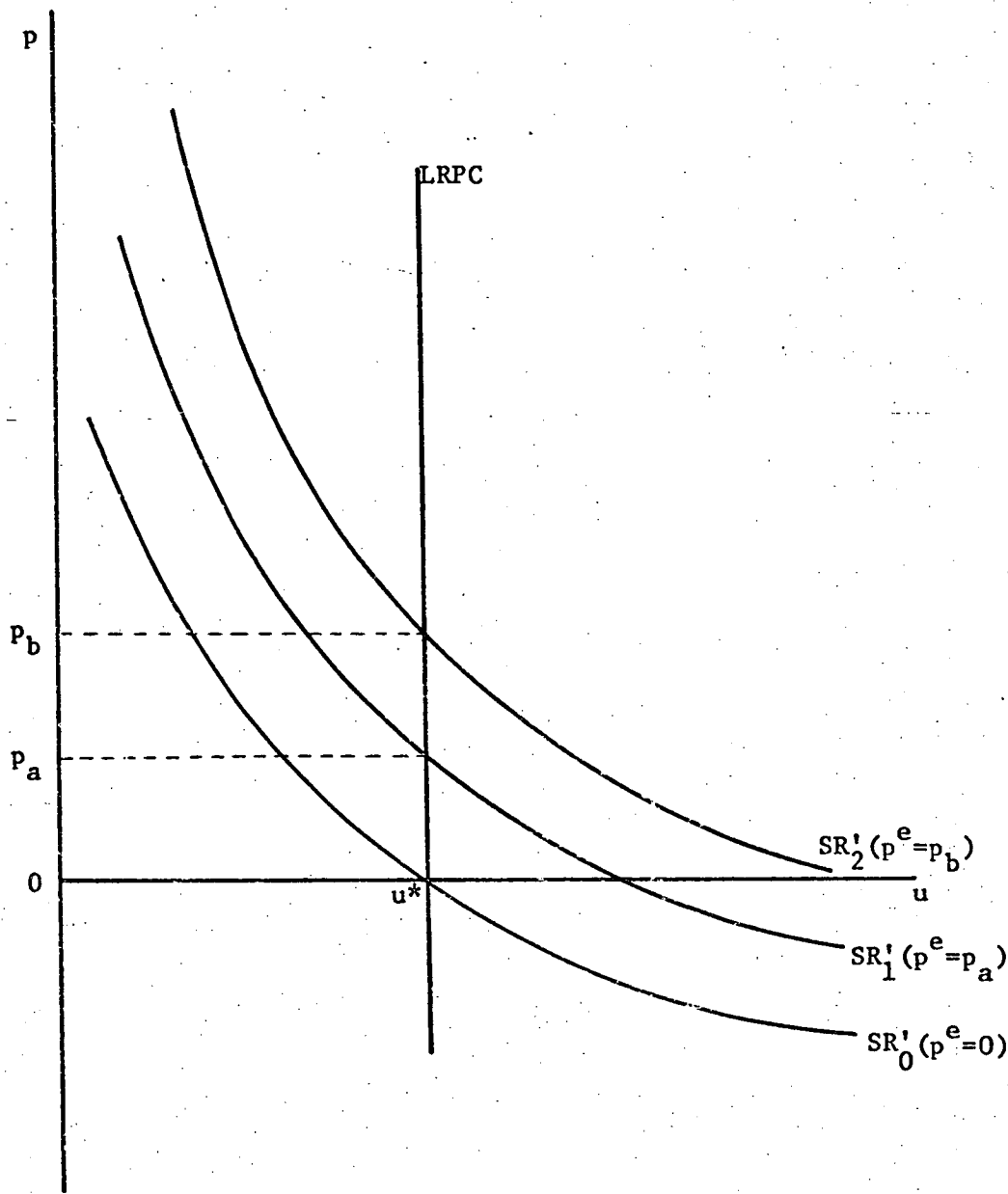


Figure 2.2

From the restrictions placed on  $\phi(u)$ , it follows from (2.7) that there is a unique unemployment rate  $u = u^*$  which is consistent with long-run equilibrium in the steady state sense.<sup>11</sup> This unemployment rate  $u^*$  is usually known as the *natural unemployment rate*. In the absence of growth in productivity ( $q = 0$ ),  $\phi(u) = f(u)$  from (2.5), so that  $u^* = \bar{u}$ , the unemployment intercept of the zero expected inflation short-run Phillips curve. In general, however, the natural unemployment rate  $u^*$  will be smaller than  $\bar{u}$ <sup>12</sup> suggesting that steady state conditions are consistent with labour market disequilibrium.<sup>13</sup>

It was established above that there is a unique unemployment rate, the natural rate  $u^*$ , which is consistent with steady-state long-run equilibrium and with the realization of inflationary expectations. It is also the case, by virtue of the meaning of the steady state, that inflationary expectations are not subject to revision when the unemployment rate is  $u^*$ . This is readily confirmed by noting that  $u^*$  is the unique unemployment rate for which  $p = p^e$  and from (2.2), the expectations adjustment equation, when  $p = p^e$ ,

11. The existence of the unemployment rate  $u^*$  is an implication of the restriction " $0 = \phi(u^*)$  for some  $u^* > 0$ " while its uniqueness follows from the monotonicity of  $\phi(u)$ . If  $\phi'(u) < 0$  (strictly) there can be only one unemployment rate for which  $\phi(u) = 0$ .
12. (2.5) is  $\phi(u) = f(u) - q$ .  $\phi(u^*) = 0$ ,  $f(\bar{u}) = 0$  and  $q \geq 0$  so  $\phi(u^*) \geq f(\bar{u}) - q$ , the equality applying only when  $q = 0$ . Since  $\phi'(u) < 0$  and  $f'(u) < 0$ ,  $u^* \leq \bar{u}$  again the equality applying only when  $q = 0$ .
13. It is frequently argued in the Phillips curve literature that the unemployment rate appears in the relationship  $w = f(u)$  as a proxy for the level of excess demand for labour, there being a well defined stable relationship between  $u$  and labour excess demand; and that labour market equilibrium occurs at the unemployment rate  $\bar{u} > 0$  for which  $f(u) = 0$ . See, for instance, Lipsey [71].

$\dot{p}^e = 0$ , that is, expectations are steady. While maintenance of unemployment at the natural rate implies steady realized expectations of the rate of inflation, nothing can be said about the rate of inflation<sup>14</sup> itself. The actual rate of inflation is indeterminate,<sup>15</sup> the natural unemployment rate being consistent with *any* fully anticipated rate of inflation. It follows immediately that there is no long-run trade-off between inflation and unemployment. The long-run Phillips curve, shown as LRPC in Figure 2.2, is a vertical line passing through  $u^*$ .

The discussion so far has established the *existence* of a unique natural unemployment rate within the framework of model A.1. The next step is to consider the dynamic properties of the model, giving special attention to the implications of maintaining the unemployment rate at a level smaller than the natural rate. For this purpose an expression is required for  $\dot{p}$ , the rate of acceleration of the inflation rate. Returning to (2.4) and differentiating with respect to time gives

$$\frac{dp}{dt} = \dot{p} = f'(u)\dot{u} + \dot{p}^e - \dot{q}$$

For convenience and without loss of generality it will be assumed that the rate of productivity growth is constant over time, i.e.  $\dot{q} = 0$ .

Hence,

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14. As opposed to expectations of that rate.

15. Because  $p$  does not enter (2.7).

$$\begin{aligned}
 \dot{p} &= f'(u)\dot{u} + \dot{p}^e \\
 &= f'(u)\dot{u} + \gamma(p - p^e) && \text{from (2.2)} \\
 &= f'(u)\dot{u} + \gamma[f(u) + p^e - q - p^e], \text{ using (2.4) again.}
 \end{aligned}$$

Tidying up produces

$$\dot{p} = f'(u)\dot{u} + \gamma[f(u) - q] \quad (2.8)$$

or 
$$\dot{p} = f'(u)\dot{u} + \gamma\phi(u), \quad (2.9)$$

using the definition (2.5). From (2.8), the determinants of the rate of acceleration of the inflation rate are the (common) slope of the family of short-run Phillips curves, the rate at which the unemployment rate changes over time, the adaptive expectations coefficient ( $\gamma$ ), the level of the unemployment rate and the rate of change of output per man.

Suppose now that the economic policy authorities take the appropriate steps to maintain the unemployment rate at some *fixed* level. In other words,  $\dot{u} = 0$ . From (2.9) the rate of acceleration of inflation given steady unemployment is then

$$\dot{p} = \gamma\phi(u) \quad (2.10)$$

If the steady unemployment rate in question is the natural rate (i.e. if  $\dot{u} = 0$  and  $u = u^*$ ), we obtain the expected result:

$$\dot{p} = \gamma\phi(u^*) = 0^{16}$$

---

16. Since, by definition of  $u^*$ ,  $\phi(u^*) = 0$ .



that the rate of inflation is steady and from (2.4),

$$\begin{aligned} p &= f(u^*) + p^e - q \\ &= \phi(u^*) + p^e, \quad \text{using (2.5)} \\ &= p^e, \end{aligned}$$

that the rate of inflation is fully anticipated. This does no more than confirm the earlier results that when  $u = u^*$  and  $\dot{u} = 0$  the system is in long-run (steady state) equilibrium with a steady, fully anticipated rate of inflation and there are no pressures for expectations of the rate of inflation to be adjusted.

Next consider the implications of maintaining the unemployment rate at a fixed level smaller than the natural rate (i.e.  $\dot{u} = 0$  and  $u < u^*$ ). As before, the rate of acceleration of inflation given steady unemployment is found from (2.10), viz:

$$\dot{p} = \gamma\phi(u)$$

In the present case, however,  $u < u^*$  which implies that  $\phi(u) > \phi(u^*)$  because  $\phi'(u) < 0$ . Hence  $\phi(u) > 0$ , in view of the fact that  $\phi(u^*) = 0$ , which implies that  $\dot{p} > 0$ . It follows that, if the unemployment rate is maintained steady below the natural rate, the rate of inflation is forever accelerating. It is from this conclusion that the exponents of Model A.1, frequently known as the "natural rate hypothesis", draw their description as "accelerationists". It can similarly be shown that the implication of maintaining a fixed unemployment rate greater than the natural rate (i.e.  $\dot{u} = 0$  and  $u > u^*$ ) is a forever decelerating rate of inflation ( $\dot{p} < 0$ ).

If the unemployment rate is rising over time (i.e.  $\dot{u} > 0$ ), the rate of acceleration of the inflation rate will be algebraically smaller at any unemployment rate than it would have been had the unemployment rate been steady. From (2.9), with the unemployment rate steady, the rate of acceleration of the inflation rate is  $\dot{p} = \gamma\phi(u)$  as was established above.<sup>17</sup> With the unemployment rate rising,  $\dot{p}$  is given by

$$\dot{p} = f'(u)\dot{u} + \gamma\phi(u)$$

$$< \gamma\phi(u),$$

in view of the restriction on  $f(u)$  that  $f'(u) < 0$ . Similarly, it is readily established that the rate of acceleration of the inflation rate will be algebraically larger at any unemployment rate when the unemployment rate is falling than it would have been had the unemployment rate been steady.

### 2.3 Prototype Model A.2

One of the features of prototype Model A.1 is that the inflationary expectations variable  $p^e$  enters the wage equation with a coefficient of unity. Model A.2 is identical in form except that the coefficient of  $p^e$  is instead restricted to be a positive fraction. Model A.2 is therefore

$$w = f(u) + \delta p^e \quad 0 < \delta < 1 \quad (2.11)$$

$$\dot{p}^e = \gamma(p - p^e) \quad 0 < \gamma < 1 \quad (2.12)$$

$$p = w - q \quad (2.13)$$

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17. See p. 31.

As before  $f(u)$  is subject to certain restrictions regarding its form.<sup>18</sup>

The wage equation (2.11) can again be thought of as a family of short-run Phillips curves each of which corresponds to a particular expected inflation rate. However, in this case the vertical difference between any two members of the family will be less than the difference in the expected inflation rates to which they correspond.

The entry of inflationary expectations into the wage equation with a coefficient of unity (as in equation (2.1) of Model A.1) is usually justified by arguing that rationality prevents there being any money illusion in the long-run and for the coefficient in question to be less than unity implies that workers are subject to a money illusion. In other words, rationality requires that workers receive full compensation for their perception of future inflation. The defect in this line of argument, advanced by the accelerationists, is that the circumstances surrounding the wage bargain are not recognized. There is an implicit assumption that workers have the *opportunity* to be fully rational. It is taken for granted that the inflationary expectations in question are those held by workers and that the entry of these inflationary expectations into the wage equation accounts for the way in which workers approach the wage bargain. A justification for the entry of inflationary expectations into the wage equation with a positive coefficient *smaller than unity* follows from the recognition that workers are only one of at least two parties to the wage bargain. The employers are always present as the second party to the wage bargain and, in countries like

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18. See above, p. 22.

Australia where a form of arbitration is enforced, the arbitrator represents a third party to the bargain. The behaviour of the other parties to the wage bargain, especially the employers, may prevent workers from behaving rationally by preventing their being fully compensated for expected inflation. Suppose to begin with that both parties to the wage bargain form the same inflationary expectation. Rational workers will bargain in such a way as to achieve full compensation for this expectation. Employers will accede to such demands only if they can be certain of passing on the resulting higher wage costs as an increase in the selling prices of their output. However, this is frequently not the case. Institutional arrangements<sup>19</sup> and the nature of the competitive environment in which the firm operates may delay upward adjustments of selling prices and may result in some part of higher wage costs being absorbed by the firm. The likely result is that an employer will resist full compensation of workers for expected inflation. In the event that workers and employers form different inflationary expectations the case for less than full compensation of workers for their perception of expected inflation is even stronger, especially if the expectations formed by workers are, on average, higher than those of their employers.

Substitution of (2.11) into (2.13) produces

$$p = f(u) + \delta p^e - q \quad (2.14)$$

which, using (2.5), can be written

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19. Such as the existence of the Prices Justification Tribunal in Australia.

$$p = \phi(u) + \delta p^e \quad (2.15)$$

in which case an equivalent statement of Model A.2 consists of (2.15) and (2.12), the required restrictions on  $\phi(u)$  again<sup>20</sup> being  $\phi'(u) < 0$ ,  $\phi''(u) > 0$ ,  $0 = \phi(u^*)$  for some  $u^* > 0$ . Using the long-run equality  $p = p^e$  in (2.15) produces

$$p = \phi(u) + \delta p$$

That is, in the long-run

$$p = \frac{1}{1 - \delta} \phi(u) \quad (2.16)$$

By virtue of the restriction  $\phi'(u) < 0$ , (2.16) has a finite negative slope  $\partial p / \partial u = (1 - \delta)^{-1} \phi'(u)$  which is numerically larger the closer is  $\delta$  to unity. Furthermore  $p$  is a monotonic function of  $u$  in the long-run as well as in the short-run. The immediate implications are that, in the long-run, there is a unique  $p$  corresponding to each  $u$  and that for every unemployment rate there is somewhere a single rate of inflation that will be both steady and fully anticipated.

Equation (2.16) defines the long-run Phillips curve and, as such, it describes the long-run trade-off between inflation and unemployment. The severity of the long-run trade-off is measured by its slope  $\partial p / \partial u = (1 - \delta)^{-1} \phi'(u)$  which, given  $\delta < 1$ , is greater in absolute value than the slope of the short-run trade-off which, from (2.15), is  $\phi'(u)$ . The relationship between the short-run and long-run Phillips curves is depicted diagrammatically in Figure 2.3.

Following the line adopted in the discussion of Model A.1, the next step is to obtain an expression for the rate of acceleration of the inflation rate. Differentiating (2.15) with respect to

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20. See above, p. 27.

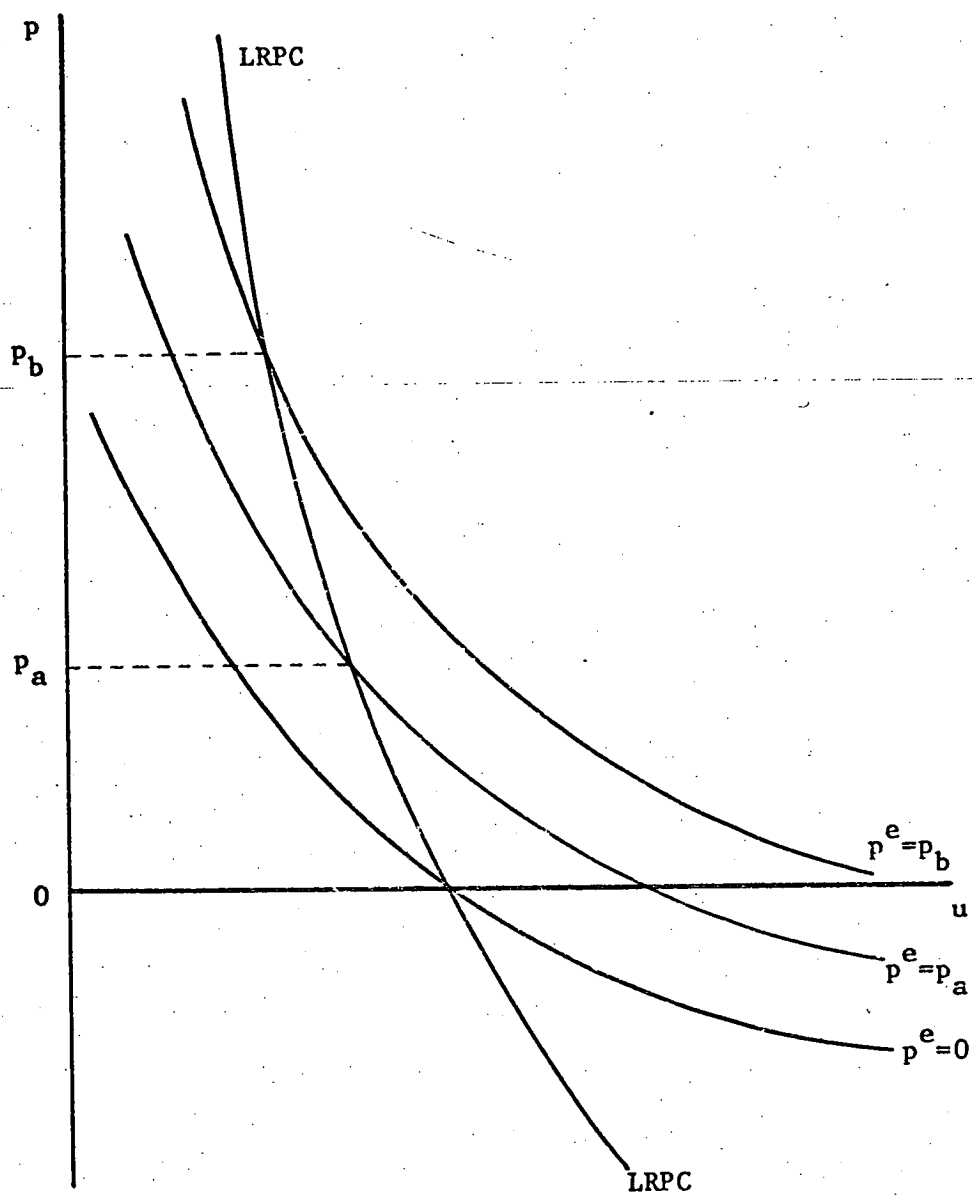


Figure 2.3

time gives

$$\frac{dp}{dt} = \dot{p} = \phi'(u)\dot{u} + \delta\dot{p}^e$$

Using (2.12),

$$\begin{aligned}\dot{p} &= \phi'(u)\dot{u} + \gamma\delta(p - p^e) \\ &= \phi'(u)\dot{u} + \gamma\delta[\phi(u) + \delta p^e] - \gamma\delta p^e, \text{ from (2.15)}\end{aligned}$$

After a little manipulation,

$$\dot{p} = \phi'(u)\dot{u} + \gamma\delta\phi(u) - \gamma\delta[1 - \delta]p^e \quad (2.17)$$

It will be recalled that an implication of Model A.1 was that  $\dot{p}$ , the rate of acceleration of the inflation rate, was non-negative for all unemployment rates equal to or smaller than the natural rate and was zero only at the natural unemployment rate,  $u = u^*$ . In view of the fact that the long-run Phillips curve of Model A.2 has a finite negative slope there is no natural rate in the sense of its definition in conjunction with Model A.1. Furthermore, as will be shown below, in Model A.2  $\dot{p}$  can be positive, negative or zero for any given unemployment rate. It is useful to begin again by assuming that the policy authorities take appropriate steps to hold the unemployment rate constant at some particular level (i.e.  $\dot{u} = 0$ ) and that the level in question is  $u = u^*$  where  $\phi(u^*) = 0$ . It should be emphasized that  $u^*$  can not be interpreted in the context of Model A.2 as the natural rate because the long-run Phillips curve is non-degenerate in this case and there is therefore no natural rate.

With  $\dot{u} = 0$ , (2.17) reduces to

$$\dot{p} = \gamma\delta\phi(u) - \gamma\delta[1 - \delta]p^e \quad (2.18)$$

and if the fixed level of the unemployment rate is  $u^*$  where  $\phi(u^*) = 0$  this becomes

$$\dot{p} = -\gamma\delta[1 - \delta]p^e \quad (2.19)$$

The rate of inflation is therefore steady ( $\dot{p} = 0$ ) only if  $p^e$  is zero.<sup>21</sup> When  $p^e$  is zero,  $\dot{p}$  is zero and, from (2.12), this can occur only if  $p = p^e$ , that is, inflationary expectations are realized or equivalently inflation is fully anticipated. Thus, an implication of Model A.2 is that in circumstances in which the unemployment rate is held fixed at  $u^*$ , inflation can be both steady and fully anticipated only if inflationary expectations are zero.

From (2.19), if the unemployment rate is held fixed at  $u^*$  and inflationary expectations are positive,  $\dot{p}$  will be negative, given  $\gamma > 0$  and  $0 < \delta < 1$ . This means that, if the *expected* rate of inflation is positive, any positive rate of inflation will be falling as long as the policy authorities hold the unemployment rate fixed at  $u^*$ . Therefore, in this situation, if the system is not at a position of steady, fully anticipated zero inflation (that is, price stability), it will be moving towards such a position.<sup>22</sup> Under

21. The restriction on  $\gamma$  ensures that  $\gamma \neq 0$  and that on  $\delta$  ensures that expectations do in fact enter the wage equation, i.e.  $\delta \neq 0$ .

22. Nothing can be said about the speed with which the system moves towards this position except that the rate of adjustment is governed by the magnitude of  $\gamma$ . The closer is  $\gamma$  to unity the faster will be the rate of adjustment.



Model A.1, maintenance of the unemployment rate at  $u^*$  produced a steady, fully anticipated but *indeterminate* inflation rate. Price stability was possible in these circumstances but no more so than any other inflation rate. Model A.2, on the other hand, implies that price stability is inevitable (at least eventually) if the unemployment rate is maintained at  $u^*$ . Furthermore, the actual rate of inflation along the way is determinate.

The next situation to be considered is again one in which the policy authorities take the necessary steps to hold the unemployment rate fixed, that is  $\dot{u}$  is again zero. However the stipulation regarding the level of the unemployment rate is now removed. Three cases will be treated. In case (i) the system is at a point above the long-run Phillips curve, in case (ii) it is at a point on that curve, while in case (iii) the system is at a point below the long-run Phillips curve (LRPC).

The point of departure for the analysis of the three cases is the result that the long-run Phillips curve for Model A.2 is given by (2.16), namely:

$$p = \frac{1}{1 - \delta} \phi(u)$$

and is the locus of points for which  $p = p^e$ .

Case (i):  $\dot{u} = 0$ , System above LRPC

A point above the long-run Phillips curve is a point  $(u, p)$  for which

$$p > \frac{1}{1 - \delta} \phi(u)$$

But, from (2.15)

$$p = \phi(u) + \delta p^e$$

Thus, a point above the long-run Phillips curve is a point for which

$$\phi(u) + \delta p^e > \frac{1}{1-\delta} \phi(u)$$

That is,

$$\delta p^e > \phi(u) \left[ \frac{1}{1-\delta} - 1 \right]$$

$$\text{i.e.} \quad \delta p^e > \phi(u) \left[ \frac{\delta}{1-\delta} \right]$$

$$\text{or} \quad p^e > \frac{1}{1-\delta} \phi(u) \quad (2.20)$$

It follows that when the unemployment rate is held fixed and the system is at a point above the long-run Phillips curve, from (2.18),

$$\dot{p} < \gamma \delta \phi(u) - \gamma \delta [1-\delta] \left[ \frac{1}{1-\delta} \phi(u) \right]$$

$$\text{i.e.} \quad \dot{p} < \gamma \delta \phi(u) - \gamma \delta \phi(u)$$

$$\text{i.e.} \quad \dot{p} < 0$$

In other words, when the unemployment rate is constant and the system is at a point above the long-run Phillips curve, the rate of acceleration of the inflation rate is negative; the inflation rate must therefore be falling and the system is moving towards the long-run Phillips curve.

Case (ii):  $\dot{u} = 0$ , System on LRPC

Any point on the long-run Phillips curve must, by definition, satisfy

$$p = \frac{1}{1 - \delta} \phi(u) = p^e$$

It then follows from (2.18) that

$$\dot{p} = 0$$

at such a position. Thus, as argued earlier, there is no tendency for the inflation rate to change when the system is at a point on the long-run Phillips curve and the unemployment rate is constant.

Case (iii):  $\dot{u} = 0$ , System below LRPC

A point below the long-run Phillips curve is a point  $(u, p)$  for which

$$p < \frac{1}{1 - \delta} \phi(u)$$

That is,

$$\phi(u) + \delta p^e < \frac{1}{1 - \delta} \phi(u) \quad \text{from (2.15)}$$

which is equivalent to

$$p^e < \frac{1}{1 - \delta} \phi(u) \quad (2.21)$$

It then follows from (2.18) that

$$\dot{p} > \gamma \delta \phi(u) - \gamma \delta [1 - \delta] \left[ \frac{1}{1 - \delta} \phi(u) \right]$$

$$\text{i.e.} \quad \dot{p} > \gamma \delta \phi(u) - \gamma \delta \phi(u)$$

$$\text{i.e.} \quad \dot{p} > 0$$

This implies that when the unemployment rate is held fixed and the system is at a point below the long-run Phillips curve, the rate of acceleration of the inflation rate is positive, which means that the inflation rate is increasing and the system is moving towards the long-run Phillips curve.

Cases (i) and (iii) establish that, for any *steady* unemployment rate, if the system is off the long-run Phillips curve the rate of inflation will be changing in such a way that the system will move towards the long-run Phillips curve. Case (ii) confirms that, for any steady unemployment rate, when the system is on the long-run Phillips curve the rate of inflation is steady and there is no tendency for the system to move off the long-run Phillips curve. The implication of these results is that, as long as the unemployment rate is held constant, the long-run Phillips curve represents a locus of fully stable equilibrium positions which can be achieved from anywhere.<sup>23</sup>

The final situation to be considered is that in which the restriction imposed up to now, that the policy authorities take appropriate steps to hold the unemployment rate fixed, is relaxed. The only restriction now imposed is that the authorities are exercising some sort of deliberate policy control over the general direction of movement of the unemployment rate or that the policy authorities are monitoring the state of the economy well enough to know whether the unemployment rate is increasing or decreasing. The situation in which the unemployment rate is not changing ( $\dot{u} = 0$ ) can be ignored as it has already been considered. The effect of the

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23. That is, from any  $(u, p)$  combination with  $\dot{u} = 0$ .

current restriction is that the sign of  $\dot{u}$  can be taken to be known.

It was shown in the course of analyzing the previous situation that, in general, at points above the long-run Phillips curve  $p$  and  $p^e$  exceed  $(1 - \delta)^{-1} \phi(u)$ , at any point on the long-run Phillips curve both  $p$  and  $p^e$  are equal to  $(1 - \delta)^{-1} \phi(u)$ , while at points below the long-run Phillips curve both  $p$  and  $p^e$  are smaller than  $(1 - \delta)^{-1} \phi(u)$ . The current situation will be considered as six separate cases ((iv) through to (ix)) according to whether the unemployment rate is rising ( $\dot{u} > 0$ ) or falling ( $\dot{u} < 0$ ) and as to whether the system is above, on or below the long-run Phillips curve (LRPC).

Case (iv):  $\dot{u} > 0$ , System above LRPC

It has been noted that a point above the long-run Phillips curve satisfies

$$p^e > \frac{1}{1 - \delta} \phi(u)$$

In these circumstances, it follows from (2.17) that

$$\begin{aligned} \dot{p} &< \phi'(u)\dot{u} + \gamma\delta\phi(u) - \gamma\delta[1 - \delta] \frac{1}{1 - \delta} \phi(u) \\ \text{i.e.} \quad \dot{p} &< \phi'(u)\dot{u} \end{aligned} \quad (2.22)$$

In view of the restriction  $\phi'(u) < 0$  and that  $\dot{u} > 0$  in this case, this means that  $\dot{p}$  is smaller than something negative, i.e. that

$$\dot{p} < 0$$

In general, therefore, if the unemployment rate is rising and the system is above the long-run Phillips curve, the inflation rate will be falling.

Case (v):  $\dot{u} > 0$ , System on LRPC

Using  $p^e = (1 - \delta)^{-1} \phi(u)$  in (2.17), gives

$$\dot{p} = \phi'(u)\dot{u} \quad (2.23)$$

when the system is on the long-run Phillips curve. Since  $\phi'(u) < 0$  and  $\dot{u} > 0$  this implies that

$$\dot{p} < 0$$

or that the inflation rate will be falling when the unemployment rate is rising and the system is on the long-run Phillips curve.

Case (vi):  $\dot{u} > 0$ , System below LRPC

In this case, it follows from (2.17) and  $p^e < (1 - \delta)^{-1} \phi(u)$ , which applies when the system is below the long-run Phillips curve, that

$$\dot{p} > \phi'(u)\dot{u} \quad (2.24)$$

As  $\phi'(u) < 0$  and  $\dot{u} > 0$ , this means that  $\dot{p}$  is greater than something negative or that the sign of  $\dot{p}$  is indeterminate. In general, it is not possible to say anything definite about the direction of change of the inflation rate or, indeed, whether it will change at all.

Case (vii):  $\dot{u} < 0$ , System above LRPC

Because the system is above the long-run Phillips curve (2.22) applies, namely:

$$\dot{p} < \phi'(u)\dot{u}$$

Given that  $\phi'(u) < 0$  and  $\dot{u} < 0$  this implies that  $\dot{p}$  is less than something positive or that the sign of  $\dot{p}$  is again indeterminate.

In this case, the inflation rate can increase, decrease or remain unchanged.

Case (viii):  $\dot{u} < 0$ , System on LRPC

The system being on the long-run Phillips curve, (2.23) applies, that is:

$$\dot{p} = \phi'(u)\dot{u}$$

$\phi'(u) < 0$  and  $\dot{u} < 0$  so this is equivalent to

$$\dot{p} > 0$$

Thus, if the unemployment rate is falling and the system is on the long-run Phillips curve then the inflation rate will be rising.

Case (ix):  $\dot{u} < 0$ , System below LRPC

In this case (2.24) applies because the system is below the long-run Phillips curve. That is:

$$\dot{p} > \phi'(u)\dot{u}$$

Using  $\phi'(u) < 0$  and  $\dot{u} < 0$  this implies that

$$\dot{p} > 0$$

or that the inflation rate will be rising when the unemployment rate is falling and the system is below the long-run Phillips curve.

The results of the analysis of the nine cases considered are summarized in Table 2.1.

TABLE 2.1<sup>a</sup>

State of the System	Unemployment Rate		
	Falling	Steady	Rising
Above LRPC	Indeterminate <sup>b</sup> (vii)	p falling (i)	p falling (iv)
On LRPC	p rising (viii)	p steady (ii)	p falling (v)
Below LRPC	p rising (ix)	p rising (iii)	Indeterminate (vi)

- a. Roman numerals in parentheses refer to Case numbers in the text.
- b. "Indeterminate" means that, in general, p can be rising, steady or falling.

The results which appear in Table 2.1 can be accounted for in a broad sense by identifying the two sources of change in the inflation rate. The first of these sources is shifts along the current short-run Phillips curve as a result of changes in the unemployment rate. The second is changes in inflationary expectations. It has already been shown that, given a steady unemployment rate, the direction of change in the inflation rate depends upon the direction of change of inflationary expectations which in turn depends upon the state of the system (reflected by the current (u, p) position) relative to the long-run Phillips curve. This general direction of change of the inflation rate resulting from changing expectations is modified (or amplified) by shifts along the current short-run Phillips curve



produced by changes in the unemployment rate. The net effect of the two influences produces the behaviour summarized in Table 2.1. The results have important implications for anti-inflation policy which will be considered in section 2.5.

## 2.4 Prototype Models B.1 and B.2

The expectations variable which enters the wage equation of both versions of Model A is the rate of inflation expected by the parties to the wage bargain. Phelps [106] has argued, in a slightly different context, that the expectations variable in question should be the rate of wage-inflation expected by employers.<sup>24</sup> Furthermore, Phelps explicitly excludes inflationary expectations by asserting that the expectation of price increases is important only through its effects on the excess demand for labour.<sup>25</sup> A further modification suggested by Phelps is that the rate of change of employment per unit of labour supply should be an argument of the Phillips curve, in addition to the unemployment rate. When the labour force grows through time at a constant rate the rate of change of employment per unit of labour supply is well proxied by the unemployment rate and its time derivative.<sup>26</sup>

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24. More correctly, the expected percentage rate of change of money wage costs per man.

25. See Phelps [106], p. 155.

26. Denoting unemployment by  $U$ , employment by  $E$  and the labour force by  $L = U + E$ , the rate of change of employment per unit of labour supply is given by  $\frac{dE}{dt} / L$ .

$$\begin{aligned} \frac{dE}{dt} &= \frac{d}{dt} (L - U) = \frac{dL}{dt} - \frac{dU}{dt} = \frac{dL}{dt} - \frac{d(Lu)}{dt} \\ &= \frac{dL}{dt} - [u \frac{dL}{dt} + L\dot{u}] \end{aligned}$$

$$\text{Hence, } \frac{dE}{dt} / L = \frac{\dot{L}}{L} (1 - u) - \dot{u}$$

where, as usual,  $u$  denotes the unemployment rate,  $\dot{u}$  its time derivative and  $\dot{L}/L$  is the labour force growth rate.

Incorporating the two modifications referred to, a "Phelpsian" version of the model is as follows.

$$w = \psi(u, \dot{u}) + \delta w^e \quad 0 < \delta \leq 1 \quad (2.25)$$

$$\dot{w}^e = \gamma(w - w^e) \quad 0 < \gamma < 1 \quad (2.26)$$

$$p = w - q \quad (2.27)$$

Certain restrictions which derive from Phelps' analysis apply to the bivariate function<sup>27</sup>  $\psi(u, \dot{u})$ . These are<sup>28</sup>

$$\psi_1 < 0 \quad \psi_{11} > 0 \quad \psi_2 < 0$$

and there exists some  $u^* > 0$  for which  $\psi(u^*, 0) = 0$ .

The cases  $\delta = 1$  and  $0 < \delta < 1$  will again be distinguished by referring to the two versions of the model as Model B.1 and Model B.2 respectively.

Thus Model B.1 is

$$w = \psi(u, \dot{u}) + w^e \quad (2.28)$$

$$\dot{w}^e = \gamma(w - w^e) \quad 0 < \gamma < 1 \quad (2.26)$$

$$p = w - q \quad (2.27)$$

As before,  $\psi_1 < 0$ ,  $\psi_{11} > 0$ ,  $\psi_2 < 0$  and  $\psi(u^*, 0) = 0$  for some  $u^* > 0$ .

27. Following conventional notation, in what follows  $\psi_i$  stands for the partial derivative of  $\psi$  with respect to its  $i$ th argument and  $\psi_{ij}$  for the second-order partial derivative of  $\psi$  with respect to the  $i$ th and  $j$ th argument in that order. Note that the notation  $\psi$  is given a different connotation by Phelps [106].

28. The restrictions on  $\psi(u, \dot{u})$  are derived from those given by Phelps [106, p. 146] for his "augmented Phillips curve"  $f(u, z)$ , where  $z$  is  $(dE/dt)/L$ , using the relationship between  $(dE/dt)/L$  and  $\dot{u}$  derived in footnote 26 above.

In the steady state all variables will persist indefinitely at unchanging levels. For this to be the case in either version of Model B, it is required that

$$\dot{w}^e = 0 \text{ and } \dot{u} = 0$$

Using (2.26),  $\dot{w}^e = 0$  if and only if  $w = w^e$ .

Hence in the long-run,<sup>29</sup> it follows from (2.28) that for Model B.1

$$w = \psi(u, 0) + w$$

That is,

$$\psi(u, 0) = 0 \tag{2.29}$$

In view of the restrictions placed on  $\psi(u, \dot{u})$ , there is a unique unemployment rate  $u = u^*$  which satisfies (2.29) and hence is consistent with long-run equilibrium in the steady state sense.<sup>30</sup>

The unemployment rate  $u^*$  can again be described as the natural unemployment rate. Following the same line of argument as was adopted in the case of Model A.1, it is readily shown that the natural rate is consistent with steady realized wage-inflation expectations and that both the actual rate of wage-inflation and the actual inflation rate are indeterminate, although related to each other via (2.27). Although there is no longer a simple graphical interpretation, there is again no long-run trade-off between inflation and unemployment because the long-run Phillips curve is a vertical line passing through  $(u, \dot{u}) = (u^*, 0)$ .

29. Using the steady-state interpretation of "long-run".  
See above, p. 26.

30. As before, the existence of the solution  $u = u^*$  to (2.29) arises from the restriction " $\psi(u^*, 0) = 0$  for some  $u^* > 0$ " and the uniqueness of that solution follows from the monotonicity of  $\psi(u, 0)$  which arises from the restriction that  $\psi_1 < 0$ .

Differentiating (2.28) with respect to time produces

$$\begin{aligned}\dot{w} &= \frac{\partial \psi}{\partial u} \cdot \frac{du}{dt} + \frac{\partial \psi}{\partial \dot{u}} \cdot \frac{d\dot{u}}{dt} + \delta \dot{w}^e \\ &= \psi_1 \dot{u} + \psi_2 \ddot{u} + \delta \gamma (w - w^e) \quad \text{from (2.26)}\end{aligned}$$

$$\text{i.e.} \quad \dot{w} = \psi_1 \dot{u} + \psi_2 \ddot{u} + \gamma \delta \psi(u, \dot{u}), \quad (2.30)$$

using (2.28) again.

From (2.27),

$$\dot{p} = \dot{w} - \dot{q}$$

Using (2.30) and again making the simplifying assumption that the percentage rate of change of output per man is constant over time (i.e.  $\dot{q} = 0$ ) leads to

$$\dot{p} = \psi_1 \dot{u} + \psi_2 \ddot{u} + \gamma \delta \psi(u, \dot{u}) \quad (2.31)$$

Equation (2.31) describes the behaviour of the rate of acceleration of the actual inflation rate. The analogous relationship in the case of Model A.1 is (2.9) and, of course, (2.31) reduces to (2.9) if  $\psi_2 = 0$ .

In circumstances where the policy authorities take appropriate steps to maintain the unemployment rate at some fixed level,  $u = \ddot{u} = 0$  and (2.31) reduces to

$$\dot{p} = \gamma \delta \psi(u, 0) \quad (2.32)$$

Hence the general conclusions which applied to this situation in the case of Model A.1 will carry over in view of the fact that (2.32)

has the same form as (2.10). When the steady unemployment rate in question is the natural rate  $u^*$ , the system will be in long-run (steady state) equilibrium with a steady, fully anticipated rate of wage-inflation and there are no pressures for wage-inflation expectations to be adjusted. Given the assumption  $\dot{q} = 0$ , the rate of inflation will also be steady and will differ from the rate of wage-inflation by  $q$ . It cannot be said that the rate of inflation is also fully anticipated because inflationary expectations do not appear in this model.

When the unemployment rate is held constant at any level smaller than the natural rate, the rate of inflation is forever accelerating. On the other hand, if the unemployment rate is held constant at a level greater than the natural rate, the actual inflation rate will forever decelerate. In each case, the rate of wage-inflation behaves in the same way as the inflation rate and differs from it by  $q$ .

The broad conclusions which applied to Model A.1 when the steady unemployment rate requirement is removed also carry over to Model B.1 as long as the unemployment rate changes linearly with respect to time (i.e.  $\dot{u} \neq 0$  but  $\ddot{u} = 0$ ). When the unemployment rate is rising, the rate of acceleration of the inflation rate (and the wage-inflation rate) will be algebraically smaller than it would have been for a steady unemployment rate. The converse applies when the unemployment rate is falling. If the unemployment rate is changing in a way that is not linear in time the result is to magnify the effect just described when  $\ddot{u}$  has the same sign as  $\dot{u}$  and to modify that effect when  $\ddot{u}$  has the opposite sign to  $\dot{u}$ . For instance, suppose that the acceleration rate of the inflation rate is  $\dot{p}_g$  when

the unemployment rate is steady at some level  $\tilde{u}$  which is smaller than the natural rate. From (2.32),  $\dot{p}_s$  is given by  $\gamma\delta\psi(\tilde{u}, 0)$  and this is positive because  $\psi_1$  is negative,  $\tilde{u} < u^*$  by supposition,  $\psi(u^*, 0) = 0$ , and each of  $\gamma$  and  $\delta$  is positive. As described above, when the requirement that  $\tilde{u}$  is a steady unemployment rate is replaced with the requirement that  $\dot{\tilde{u}} > 0$  and  $\ddot{u} = 0$ , the resulting rate of acceleration of the inflation rate, call it  $\dot{p}_r$ , will be smaller than  $\dot{p}_s$ . From (2.31),

$$\dot{p}_r = \psi_1 \dot{\tilde{u}} + \dot{p}_s \quad (2.33)$$

But  $\dot{\tilde{u}} > 0$  while  $\psi_1 < 0$  so  $\dot{p}_r < \dot{p}_s$ . If the zero restriction on  $\ddot{u}$  is also removed, the rate of acceleration of the inflation rate, call it  $\dot{p}_v$ , is given, from (2.31) and (2.33), by

$$\dot{p}_v = \dot{p}_r + \psi_2 \ddot{u}$$

Given that  $\psi_2 < 0$ , with  $\ddot{u} > 0$ ,  $\dot{p}_v < \dot{p}_r < \dot{p}_s$ . Thus when the unemployment rate is below the natural rate and increasing, the inflation rate will accelerate more slowly than it would have done had the unemployment rate been steady. The faster is the unemployment rate increasing, the smaller will be the acceleration rate of the rate of inflation.

The second version of Model B, prototype Model B.2, is

$$w = \psi(u, \dot{u}) + \delta w^e \quad 0 < \delta < 1 \quad (2.34)$$

$$\dot{w}^e = \gamma(w - w^e) \quad 0 < \gamma < 1 \quad (2.35)$$

$$p = w - q \quad (2.36)$$

and the restrictions on  $\psi$  are again

$$\psi_1 < 0 \quad \psi_{11} > 0 \quad \psi_2 < 0$$

and  $\psi(u^*, 0) = 0$  for some  $u^* > 0$ .

To obtain an expression for the long-run Phillips curve, we impose the steady state conditions  $\dot{w}^e = 0$  (which implies  $w = w^e$  from (2.26)) and  $\dot{u} = 0$  on (2.34). This gives

$$w = \psi(u, 0) + \delta w$$

Hence, 
$$w = \frac{1}{1 - \delta} \psi(u, 0) \quad (2.37)$$

Using (2.36),

$$p = \frac{1}{1 - \delta} \psi(u, 0) - q \quad (2.38)$$

As was the case in Model A.2, the long-run Phillips curve of Model B.2, (2.38), is non-degenerate having the finite negative slope  $\partial p / \partial u = (1 - \delta)^{-1} \psi_1$  which is numerically greater than that of the members of the family of short-run Phillips curves and which becomes numerically larger the closer is  $\delta$  to unity. Given  $q$ , (2.38) shows that  $p$  is again a monotonic function of  $u$  in the long-run, from which it follows that, in the long-run, there is a unique inflation rate corresponding to a given steady unemployment rate that is consistent with both steady and fully anticipated wage-inflation.

Following the well-established precedent, the next step is to obtain an expression for the rate of acceleration of the inflation rate. Differentiating (2.34) with respect to time produces

$$\dot{w} = \psi_1 \dot{u} + \psi_2 \ddot{u} + \delta \dot{w}^e$$

Substituting for  $\dot{w}^e$  from (2.35),

$$\begin{aligned} \dot{w} &= \psi_1 \dot{u} + \psi_2 \ddot{u} + \gamma \delta (w - w^e) \\ &= \psi_1 \dot{u} + \psi_2 \ddot{u} + \gamma \delta [\psi(u, \dot{u}) + \delta w^e] - \gamma \delta w^e, \end{aligned}$$

from (2.34)

Tidying up,

$$\dot{w} = \psi_1 \dot{u} + \psi_2 \ddot{u} + \gamma \delta \psi(u, \dot{u}) - \gamma \delta (1 - \delta) w^e \quad (2.39)$$

As before, an expression for  $\dot{p}$  can then be obtained by substituting (2.39) into  $\dot{p} = \dot{w} - \dot{q}$  and imposing the simplifying assumption that  $\dot{q} = 0$ . The result is

$$\dot{p} = \psi_1 \dot{u} + \psi_2 \ddot{u} + \gamma \delta \psi(u, \dot{u}) - \gamma \delta (1 - \delta) w^e \quad (2.40)$$

In the current context, the long-run Phillips curve (2.38) is a line in the three-dimensional space  $(u, \dot{u}, p)$  and lies entirely within the  $(u, 0, p)$  plane. Accordingly, to analyze the behaviour of the rate of acceleration of the inflation rate in the same way as applied in the case of Model A.2, initial  $(u, \dot{u}, p)$  positions of the system have to be classified as to (a) whether the initial position is above, below or on the surface defined by  $p = (1 - \delta)^{-1} \psi(u, \dot{u}) - q$ ,<sup>31</sup> (b) whether in the initial position the unemployment rate is falling, steady or rising<sup>32</sup> and (c) whether in the initial position  $\ddot{u}$  is positive, negative or zero. Such a classification produces twenty-seven separate cases to be analyzed. A summary of the results of analysis of these cases is presented in Table 2.2. In view of the fact that the development of these results is very similar to those which underly those summarized in Table 2.1, they will not be considered in any detail. However, some general results underlying them are presented below.

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31. This consideration is analogous to classifying an initial position in Model A.2 according to whether it lay above, below or on the long-run Phillips curve of that model. In the case of the current model, B.2, the long-run Phillips curve is the line along which the surface  $p = (1 - \delta)^{-1} \psi(u, \dot{u}) - q$  intersects the plane  $(u, 0, p)$ .

32. Equivalently, whether the system was to the left, on or to the right of the  $(u, 0, p)$  plane.



At positions on the surface  $p = (1 - \delta)^{-1} \psi(u, \dot{u}) - q$ , which will also be referred to as  $\{\Sigma\}$ , the following holds by virtue of (2.34) and (2.36):

$$\begin{aligned} \psi(u, \dot{u}) + \delta w^e - q &= (1 - \delta)^{-1} \psi(u, \dot{u}) - q \\ \text{i.e.} \quad \delta w^e &= [(1 - \delta)^{-1} - 1] \psi(u, \dot{u}) \\ \text{or} \quad w^e &= (1 - \delta)^{-1} \psi(u, \dot{u}) \end{aligned} \quad (2.41)$$

Similarly, at positions above the surface  $\{\Sigma\}$ ,

$$p > (1 - \delta)^{-1} \psi(u, \dot{u}) - q$$

by definition, and it can easily be shown that

$$w^e > (1 - \delta)^{-1} \psi(u, \dot{u}) \quad (2.42)$$

Finally, at positions below the surface  $\{\Sigma\}$ ,

$$p < (1 - \delta)^{-1} \psi(u, \dot{u}) - q$$

and

$$w^e < (1 - \delta)^{-1} \psi(u, \dot{u}) \quad (2.43)$$

Using (2.40) and (2.41), at points on the surface  $\{\Sigma\}$ ,

$$\begin{aligned} \dot{p} &= \psi_1 \dot{u} + \psi_2 \ddot{u} + \gamma \delta \psi(u, \dot{u}) - \gamma \delta (1 - \delta) (1 - \delta)^{-1} \psi(u, \dot{u}) \\ \text{i.e.} \quad \dot{p} &= \psi_1 \dot{u} + \psi_2 \ddot{u} \end{aligned} \quad (2.44)$$

Similarly, using (2.40) and (2.42), it can be shown that at points above the surface  $\{\Sigma\}$ ,

$$\dot{p} < \psi_1 \dot{u} + \psi_2 \ddot{u} \quad (2.45)$$

while for points below  $\{\Sigma\}$ , it follows from (2.40) and (2.43) that

$$\dot{p} > \psi_1 \dot{u} + \psi_2 \ddot{u} \quad (2.46)$$

The contents of Table 2.2 can then be obtained from (2.44), (2.45) and (2.46) using the restrictions  $\psi_1 < 0$  and  $\psi_2 < 0$ .

TABLE 2.2

State of the System	Unemployment Rate		
	Falling	Steady	Rising
$\ddot{u} > 0$ and: Above $\{\Sigma\}$ On $\{\Sigma\}$ Below $\{\Sigma\}$	Indeterminate <sup>a</sup> Indeterminate Indeterminate	p falling p falling Indeterminate	p falling p falling Indeterminate
$\ddot{u} = 0$ and: Above $\{\Sigma\}$ On $\{\Sigma\}$ Below $\{\Sigma\}$	Indeterminate p rising p rising	p falling p steady p rising	p falling p falling Indeterminate
$\ddot{u} < 0$ and: Above $\{\Sigma\}$ On $\{\Sigma\}$ Below $\{\Sigma\}$	Indeterminate p rising p rising	Indeterminate p rising p rising	Indeterminate Indeterminate Indeterminate

a. "Indeterminate" means that, in general, p can be rising, steady or falling.

## 2.5 Policy Implications of the Prototype Models

In the preceding sections of this chapter four separate expectations hypothesis models have been described and their behavioural implications discussed in detail. The object of the current section is to consider the implications of these models for the formulation of anti-inflation policy by the economic policy authorities. It has appeared from the discussion of the behavioural implications of the models that Models B.1 and B.2 can be looked upon as refinements of Models A.1 and A.2 respectively, in that while there are differences of detail, the behavioural implications of the former models do not differ in any essential way from their respective counterparts in the latter pair of models. Accordingly the anti-inflation policy implications of Models A.1 and A.2 only will be considered.

An assumption must be made at the outset regarding the policy maker's objectives in pursuing anti-inflation policy. It will be assumed that the policy maker has separate desires for the unemployment rate  $u$  and for the inflation rate  $p$ , and that the policy maker requires that, once achieved, his desired inflation rate is a *steady* rate.<sup>33</sup> These desires will be denoted by  $u^D$  and  $p^D$  respectively. For simplicity and without loss of generality it will be assumed throughout this section that  $u^D \leq u^*$ . It will further be assumed that the policy maker has sufficient demand management instruments to enable him to manipulate the unemployment rate as he wishes.

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33. A policy maker who did not impose the steady  $p$  requirement would not be rational because his desired inflation rate might actually be achieved only for an instant of time.

Perhaps the most important result of the discussion of Section 2.2 was that for Model A.1, maintenance of unemployment at any level other than the natural rate  $u^*$  will produce a forever accelerating inflation rate while maintenance of unemployment at the natural rate is consistent with *any* steady inflation rate. It follows immediately that the policy maker cannot simultaneously achieve his desires for both  $u$  and  $p$  unless  $u^D = u^*$ . For any other desired unemployment rate, a steady inflation rate is impossible. Therefore, in circumstances in which  $u^D$  is different from  $u^*$ , the policy maker has to face accelerating inflation or higher than desired unemployment or both. In these circumstances there is no trade-off between steady inflation and unemployment, and the only option open to the policy maker is to attempt to reduce the natural unemployment rate. Policies designed to do this are aimed at reducing imperfections in the labour market and will not be considered here.<sup>34</sup>

Suppose now that the policy maker has taken such steps as are required to bring the unemployment rate to its natural rate  $u^*$  but that the current inflation rate  $p_0$  is higher than the desired rate  $p^D$ . Given that  $u = u^*$ , the current inflation rate  $p_0$  will be steady. This situation is portrayed in Figure 2.4. The current short-run Phillips curve is  $SR_0$  and this is the member of the family of such curves corresponding to  $p^e = p_0$ . If the level of unemployment is then increased to  $u_1$  there will be a shift along the current short-run Phillips curve  $SR_0$ , the effect of which is to reduce the actual inflation rate to  $p_1$ . At  $(u_1, p_1)$  the actual inflation rate  $p_1$  is smaller than the expected inflation rate  $p_0$ .

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34. See, however, Holt [53], pp. 242-252.



Inflationary expectations will therefore be revised downwards, shifting the short-run Phillips curve to a position like  $SR_1$ . A further reduction in the actual inflation rate to  $p_2$  occurs as a result. Another downward revision of inflationary expectations will then take place. This adjustment process can be allowed to continue until the short-run Phillips curve  $SR_D$  corresponding to  $p^e = p^D$  is achieved. At this time the actual inflation rate ( $p_3$ ) will be smaller than desired. However, if the unemployment rate is then contracted back to  $u^*$  a shift occurs along  $SR_D$  which results in achievement of  $u^*$  and the *steady* inflation rate  $p^D$ . In this way any desired steady inflation rate can be achieved as long as the desired unemployment rate is the natural rate and a temporary period of higher than desired unemployment is tolerated.

The adjustment path from the initial position ( $u^*, p_0$ ) to the desired position ( $u^*, p^D$ ) just described is by no means unique. The same desired position can be achieved by temporarily raising the unemployment rate to any other level greater than  $u^*$ . The speed of adjustment may however be different for different unemployment rates greater than  $u^*$  maintained temporarily.<sup>35</sup> Further, the desired position can be achieved by increasing the unemployment rate to a level greater than  $u^*$  and allowing it to then fall back rather slowly to  $u^*$ . One such adjustment path is shown in Figure 2.5. The initial position is again ( $u^*, p_0$ ). The policy maker takes the necessary steps to increase the unemployment rate to  $u_1$ , the immediate effect of which is to produce a shift along the current short-run Phillips curve  $SR_0$  resulting in a reduction of the actual inflation rate to  $p_1$ .

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35. This question is considered below. See p. 68.

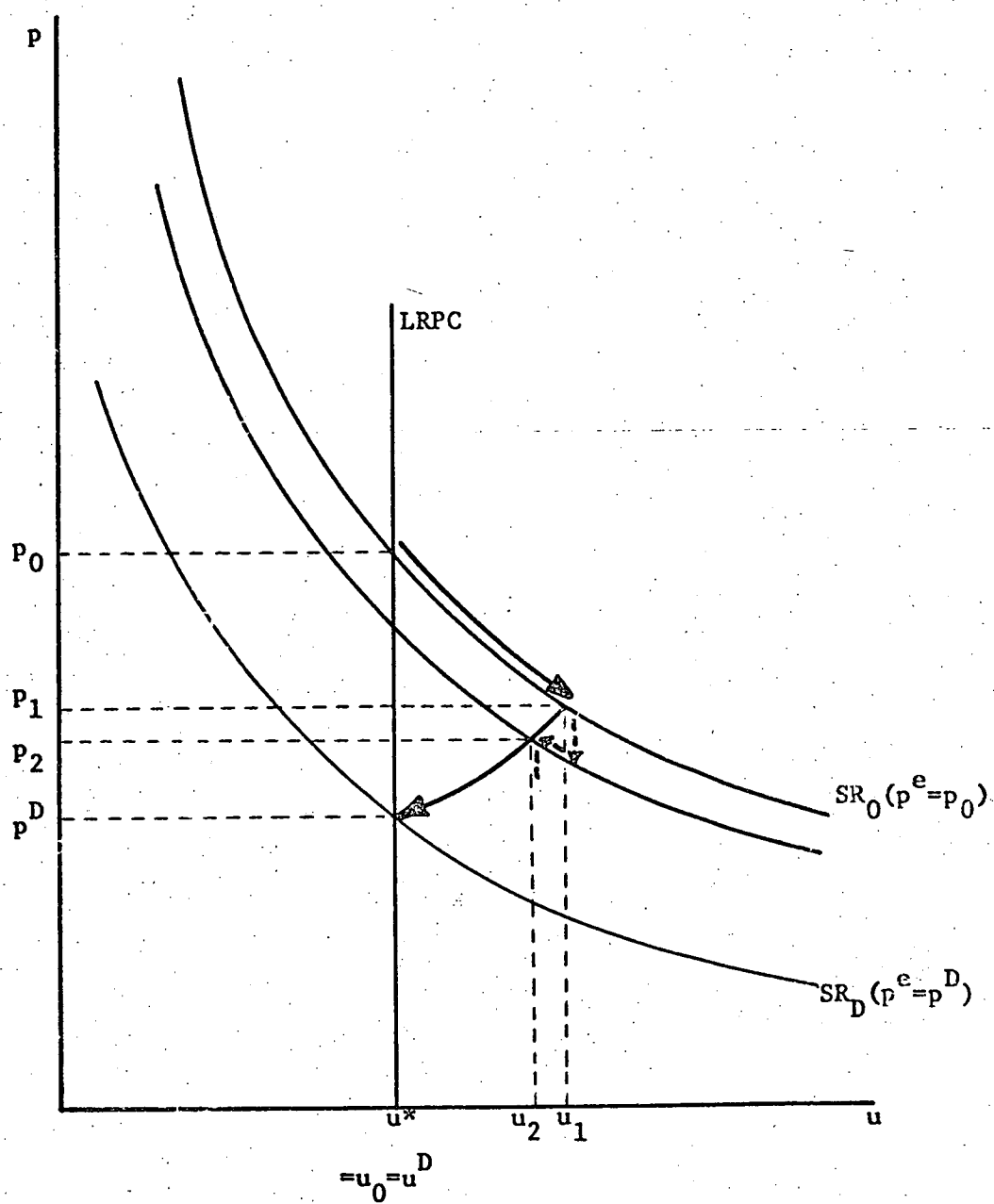


Figure 2.5

The expected inflation rate then exceeds the actual inflation rate which results in downward revision of those inflationary expectations. If at the same time as this revision of expectations is taking place, the policy maker brings about a steady but relatively slow reduction in the unemployment rate, the combined effect of downward shifts in the short-run Phillips curve produced by revision of inflationary expectations and shifts along those short-run Phillips curves produced by adjustments to the unemployment rate is to result in an adjustment path of the form of the bold arrows in Figure 2.5.

It is clear that there is a different adjustment path from the initial position  $(u^*, p_0)$  to the "desired" position  $(u^*, p^D)$  corresponding to every conceivable time path for the unemployment rate. As such there is an infinite number of possible adjustment paths from any initial position on the long-run Phillips curve to any desired position on that curve. The only requirement is that the unemployment rate is higher than  $u^*$  while the adjustment process takes place. The difference between various adjustment paths is that the time required to move from the initial to the desired position may differ.

The distinguishing feature of Model A.2 is that there is a long-run trade-off between inflation and unemployment, the long-run Phillips curve having a finite negative slope. Furthermore, there is no natural unemployment rate for this model. The implication is that under Model A.2 the policy maker can choose and simultaneously achieve separate desired values for the unemployment rate and a steady inflation rate, the only proviso being that the desired  $(u, p)$  combination lies on the long-run Phillips curve.



There is again an infinite number of possible paths by which a desired  $(u, p)$  combination on the long-run Phillips curve can be achieved from any given initial  $(u, p)$  position. Several such adjustment paths are depicted in Figure 2.6. The initial position of the system is  $(u_0, p_0)$ , in which both the unemployment rate and the rate of inflation exceed the policy maker's desired values, the desired position being  $(u^D, p^D)$ . Because the initial position lies above the long-run Phillips curve (LRPC) the inflation rate will be falling.<sup>36</sup> The desired  $(u, p)$  combination lies on the long-run Phillips curve so, once achieved, it will be maintained indefinitely given that the unemployment rate is held fixed because the desired inflation rate will be a steady one.

One adjustment path which the policy maker might contemplate requires that initially he do no more than maintain the unemployment rate at its initial level  $u_0$ . In view of the fact that the initial position  $(u_0, p_0)$  lies above the long-run Phillips curve the rate of inflation will be falling. If the unemployment rate is unchanged, this will continue until the long-run Phillips curve is reached at  $(u_0, p_1)$ . Attainment of the position  $(u_0, p_1)$  on LRPC will be signalled by the inflation rate becoming steady. There is then a variety of paths by which the policy maker can bring about the movement from  $(u_0, p_1)$  to the desired position. One approach is to take the appropriate steps to shift the unemployment rate straight to the desired level  $u^D$ . The immediate effect will be to bring about a shift along the current short-run Phillips curve  $SR_1$  to  $(u^D, p_2)$  which causes the actual inflation rate to increase from  $p_1$  to  $p_2$ .

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36. See above, p. 41.

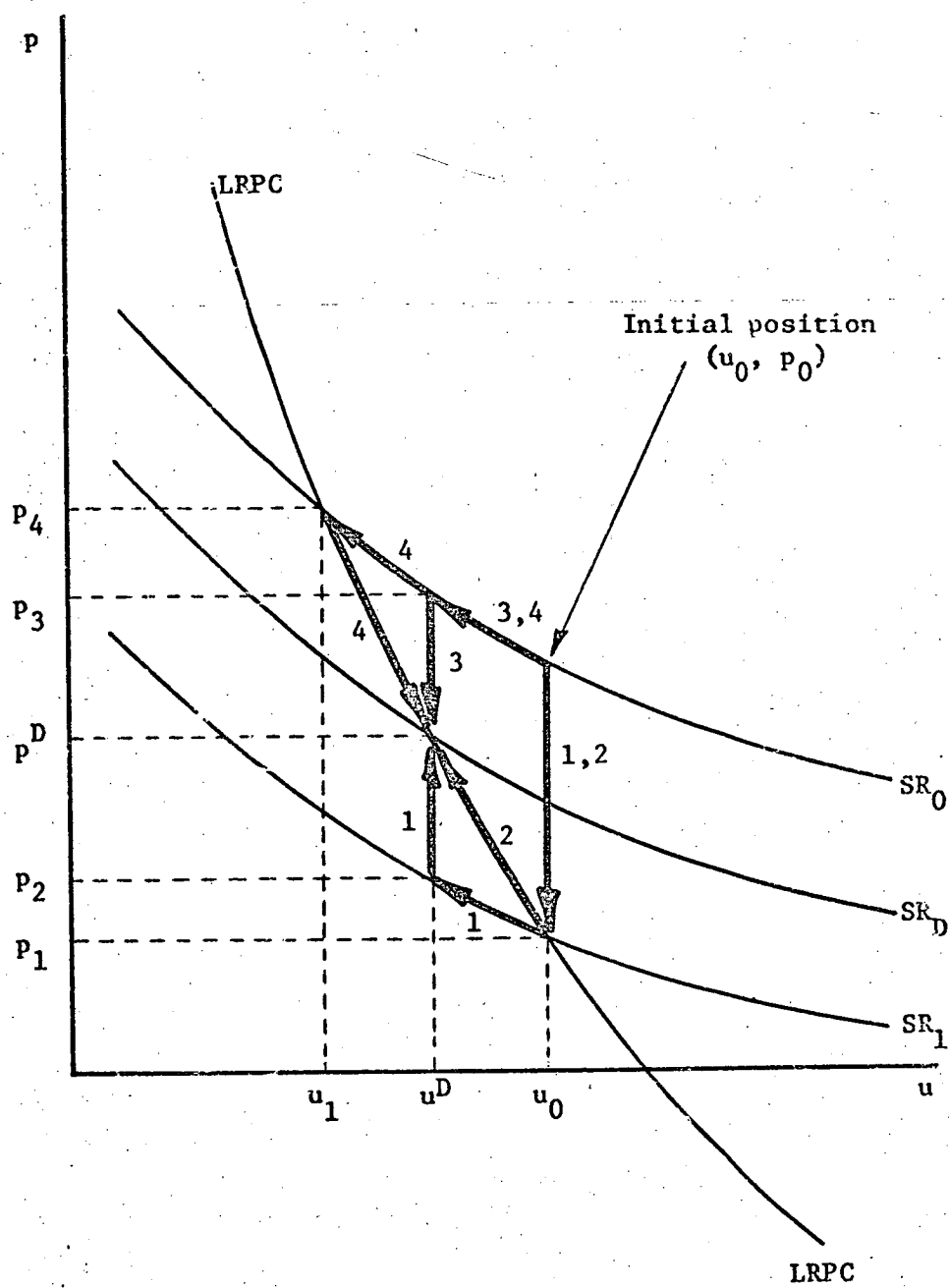


Figure 2.6

At this point, the system is below LRPC so maintenance of the unemployment rate at  $u^D$  will eventually result in achievement of the desired position  $(u^D, p^D)$  through upward revision of inflationary expectations and the consequent shifting of the short-run Phillips curve in the same way as described previously. This adjustment path is shown in Figure 2.6 as the bold arrows marked 1. An alternative path from  $(u_0, p_1)$  to the desired position is for the policy maker to bring about a gradual reduction in the unemployment rate from  $u_0$  to  $u^D$ . This action will produce small shifts along the current short-run Phillips curve upwards and to the left at the same time as the curve itself is shifting upwards as a result of revisions of inflationary expectations. The combination of these shifts of and along the short-run Phillips curve can be thought of approximately as a movement upwards along LRPC from  $(u_0, p_1)$  to the desired position  $(u^D, p^D)$ . This path appears in Figure 2.6 as the arrows marked 2.

Returning to consider again the initial position  $(u_0, p_0)$ , a third path (the arrows marked 3 in Figure 2.6) is for the policy maker to bring about an immediate reduction in the unemployment rate, producing a shift along  $SR_0$  to  $(u^D, p_3)$  and increasing the actual inflation rate to  $p_3$ . The resulting position lies above LRPC which means that the desired position will be achieved eventually without further intervention by the policy maker.

Finally, consider the path denoted by the arrows marked 4 in Figure 2.6. In this case the policy maker achieves a shift along  $SR_0$  to  $(u_1, p_4)$  by reducing the unemployment rate to  $u_1$ . This position lies on LRPC and, as such, is characterized by steady inflation. The policy maker then brings about a gradual increase in

the unemployment rate from  $u_1$  to the desired level  $u^D$ . This again can be thought of approximately as resulting in a shift down LRPC from  $(u_1, p_4)$  to  $(u^D, p^D)$ . Strictly speaking, however, the resulting path is the combined effect of downward shifts of the short-run Phillips curve produced by revisions of inflationary expectations and of shifts along the curve (downwards and to the right) produced by changes in the unemployment rate.

Given that there is an enormous variety of paths from  $(u_0, p_0)$  to  $(u^D, p^D)$  from which the policy maker must choose, it is natural to ask how the policy maker will make his decision as to which path to adopt. Before attempting any answer to this question, it is necessary to note the characteristics of the various paths. Two important characteristics can be identified - the extent to which a given path offends the policy maker's desires for  $u$  and  $p$ ; and the time required to achieve the desired position by a given path. A third characteristic which may be of interest to the policy maker is the extent to which he must intervene in the operation of the system to achieve the desired position via a given path.

The three characteristics just identified can then be used to describe the four adjustment paths of Figure 2.6. If path 1 is adopted, the inflation rate will be higher than desired for part of the time and less than desired for part of the time while the unemployment rate is greater than desired all the time. Path 2 has identical features to path 1 as far as the extent of offence to the policy maker's desires is concerned. In the case of path 3, the inflation rate exceeds the desired rate all the time until  $(u^D, p^D)$  is achieved while the unemployment rate is equal to the desired value for virtually the whole time taken by the adjustment process.

Finally, for path 4, the unemployment rate is smaller than desired virtually all the time while the inflation rate exceeds its desired value all the time. If it were the case that the time taken to achieve the desired position was the same for all possible paths, the policy maker could then select the particular path which gave least offence to his desires. Thus a policy maker endowed with a high excessive unemployment aversion (relative to his excessive inflation aversion) would select a path like 3 or 4. If, on the other hand, the policy maker had a relatively high aversion to excessive inflation, a path like 1 or 2 would be selected. However, as will be suggested below, the time taken to achieve the desired position given the initial position is not the same for all paths. Hence the second characteristic of the adjustment paths is also relevant to the policy maker's selection of a particular path.

The question of the speed of adjustment has not been considered in any depth anywhere in the literature. However, there appears to be general agreement that the rate of inflation changes faster the higher is the unemployment rate. A typical comment on this point is that of Laidler [67, p. 85] who states that "One can bring inflation to a halt quickly by having more unemployment for a relatively short time, or slowly by having less unemployment for a longer time", and later goes on to say [67, p. 93] that "... the policy trade-off when seeking to reduce the rate of inflation is between a rapid reduction associated with a relatively short period of 'high' unemployment and a slow reduction associated with the existence of 'low' unemployment over a longer period".

The final characteristic of the adjustment paths concerns the extent of intervention required of the policy maker. In the case of paths 1 and 3 a single change in the unemployment rate is required with no other intervention. Path 2 requires of the policy maker a gradual reduction in the unemployment rate while path 4 requires an initial decrease in the unemployment rate and then a gradual increase back to the desired unemployment rate. Assuming that the policy maker prefers as little intervention as possible, path 4 is the least desirable. Paths 1 and 3 come next in the ranking and path 2 is the most preferred on the minimization of intervention criterion.

It appears from the preceding discussion that no straightforward ranking of the various adjustment paths is possible, at least not without having the benefit of empirical estimates of the parameters involved. If such estimates are available then it should be possible to use simulation techniques to provide the policy maker with sufficient information about the characteristics of the various adjustment paths for him to decide upon a ranking and then to select a particular path.

## CHAPTER THREE

### EMPIRICAL STUDIES - PROTOTYPE MODELS

#### 3.1 Introduction

The objective of this chapter is to review those contributions to the empirical literature of the expectations hypothesis which are directly relevant to the four prototype models specified and analyzed in Chapter Two. The emphasis will be on the broad approach adopted in the studies concerned, rather than on the details of estimation, choice of data and the like. This seems appropriate since the main aim of the review is to provide a starting point for the task to be undertaken in the next chapter - the task of deciding how the question of the appropriateness of the prototype models for the Australian economy is to be approached.

To date empirical work relevant to the prototype models has been carried out by Solow [120] and Turnovsky and Wachter [134] for the United States, by Solow [120] and Parkin [89] for the United Kingdom, by Toyoda [129] for Japan, and by Turnovsky [131], Donner and Lazar [20] and Vanderkamp [136] for Canada. Three broad approaches, which will be referred to as the Proxied Expectations (PE) approach, the Observed Expectations (OE) approach and the Reduced Form (RF) approach,<sup>1</sup> can be identified in these studies. The nature of each of these three approaches will become clear as the chapter proceeds

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1. It should be noted that the names of the three approaches have been coined for the purposes of this thesis and are not found elsewhere in the literature.

and, in addition, each is examined critically in Chapter Four. The PE approach is followed in the studies of Solow [120], Toyoda [129] and Vanderkamp [136]. These studies are considered in section 3.2. The RF approach formed the basis for the studies of Parkin [89] and Donner and Lazar [20]. These studies and the parts of those of Turnovsky [131] and Turnovsky and Wachter [134] in which the RF approach was used, are examined in section 3.3. Finally, the remaining parts of the Turnovsky [131] and Turnovsky and Wachter [134] studies in which the OE approach was used are considered in section 3.4.<sup>2</sup>

### 3.2 Studies Based on the PE Approach

The originator of the Proxied Expectations (PE) approach was Solow [120] who used it to examine a variant of prototype Model A.2 for both the United States and the United Kingdom. While Solow's study is perhaps not strictly relevant to the prototype models it is considered here by virtue of its being both the first and the best example of the use of the PE approach.

The PE approach is based on the generation of an artificial, or proxy expected rate of inflation series. This necessitates the adoption first of a particular form for the expectations adjustment equation. The form chosen by Solow was the adaptive scheme:<sup>3</sup>

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2. A study by Brechling [9] might be considered relevant to the prototype models but will not be reviewed here because the approach, apart from being unusual, requires quite restrictive assumptions about the behaviour of the policy maker to arrive at testable propositions.
  3. The notation throughout this chapter conforms to that adopted in Chapter Two. Where necessary the notation of the original article in question has been appropriately modified.



$$p_t^e - p_{t-1}^e = \gamma(p_{t-1} - p_{t-1}^e) \quad 0 < \gamma < 1 \quad (3.1)$$

This can be rewritten in the form

$$p_t^e = \gamma p_{t-1} + (1 - \gamma)p_{t-1}^e \quad (3.2)$$

Given the available historical series for  $p$ , an initial value for  $p^e$  and a value for the parameter  $\gamma$ , a series for  $p^e$  can be generated recursively from (3.2). Solow tried the values 0.1, 0.2, ..., 0.8, 0.9 for  $\gamma$ . For each of these he adopted as the initial value for  $p^e$ ,  $p_b^e = 0$  where  $b$  denotes first quarter 1929.<sup>4</sup> For the first value of  $\gamma$ ,  $\gamma = 0.1$ , a series for  $p^e$  for the period 1929(1) to 1966(4) was generated by Solow by substituting the known observations on  $p$  into

$$p_t^e = 0.1p_{t-1} + 0.9p_{t-1}^e$$

with  $p_b^e = 0$  for  $b = 1929(1)$ . The resulting series is denoted by  $p_t^e(0.1)$  to emphasize its conditionality on the chosen value  $\gamma = 0.1$ . The period for which Solow's study was undertaken was 1948(1) to 1966(4) so that values of  $p_t^e(0.1)$  for  $t = 1948(1)$  to 1947(4) were discarded. Solow then assumed that any distortion introduced by the choice of the initial  $p^e$  value ( $p_b^e = 0$ ,  $b = 1929(1)$ ) would have disappeared by 1948(1), the start of the sample period of the study. The process just described was repeated for each of the remaining eight values for  $\gamma$  to produce a set of nine proxy  $p^e$  series  $p_t^e(\gamma)$ ,  $\gamma = 0.1, 0.2, \dots, 0.9$ .

Consideration of the "real" determinants of the rate of inflation led Solow to the following relationship.

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4. Hereafter 1929(1) denotes quarter 1 of 1929, 1929(2) quarter 2 of 1929, and so on.

$$p_t = a_0 + a_1 w_t + a_2 \bar{r}_t + a_3 f_{st} + a_4 NCU_t + a_5 K_t + a_6 G_t + a_7 p_t^e(\gamma) \quad (3.3)$$

where  $\bar{r}$  denotes the rate of change of a five-quarter moving average of labour requirements per unit of output and is interpreted as a measure of productivity after elimination of short-run fluctuations;  $f_s$  is a trend-adjusted four-quarter proportional change of the price index for farm product;<sup>5</sup> NCU is a non-linear index of capacity utilization;<sup>6</sup> K and G are dummy variables designed to capture respectively the influence of the Korean War and the informal incomes policy guidelines in force in the United States after 1962; and  $p_t^e(\gamma)$  is the proxy expected rate of inflation series described above. The relevance of Solow's study to the prototype models is clear in view of the fact that (3.3) can be looked upon as combining a modified prototype price and wage equation with NCU playing a similar role to that of  $f(u)$  in the prototype models. Equation (3.3) was estimated by OLS for each of the nine chosen values of  $\gamma$ , with  $p_t^e(\gamma)$  omitted (corresponding to the case  $\gamma = 0$ ), and with  $p_{t-1}$  in place of  $p_t^e(\gamma)$  (this corresponding to  $\gamma = 1$ ). Solow found that the inclusion of  $p_t^e(\gamma)$  improved the performance of the relationship, that the estimate of the coefficient of  $a_7$  was relatively insensitive to the value of  $\gamma$  (the estimate varied between 0.37 and 0.55 with consistently high t-ratios varying between 4.9 and 9.4) and that the higher the value of  $\gamma$  the better the econometric performance of the estimated relationship. With  $\gamma = 1.0$ , that is  $p_t^e(\gamma) = p_{t-1}$ , the estimate of

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5. See [120, p. 10].

6. See [120, pp. 10-11].

$a_7$  was 0.55 and its t-ratio 9.4. The implication is that there is a quite considerable long-run "trade-off" between  $p$  and NCU. In the long-run a unit increase in NCU will bring about an increase in the rate of inflation of about 2.6 points, this being about twice the short-run figure of 1.2 points.<sup>7</sup>

Toyoda's [129] examination of the expectations hypothesis for the post-war Japanese economy is very similar, as regards general approach, to Solow's study but is directly relevant to the prototype models in that a wage equation of the form specified for the prototype models is employed. Like Solow, Toyoda adopts the adaptive scheme (3.1) or (3.2) and generates ten proxy series for the expected rate of inflation ( $p_t^e(\gamma)$ ) corresponding to the ten values  $\gamma = 0.1, 0.2, \dots, 1.0$ . His initial  $p^e$  value in each case is  $p_b^e = 0$  for  $b = 1956(1)$ , the first period of the sample period. A wage equation of the form

$$w = a_0 + a_1 u^{-1} + a_2 \dot{Y} + a_3 p_t^e(\gamma) \quad (3.4)$$

where  $\dot{Y}$  denotes the rate of change of real GNP, is then estimated (by OLS) for each of the ten proxy  $p^e$  series. From the ten estimations the equation having the highest value of  $\bar{R}^2$  is selected as the preferred equation. The preferred equation is:<sup>8</sup>

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7. The estimate of  $a_4$  in the  $\gamma = 1.0$  estimation is 0.0116. Thus the short-run  $p$  - NCU "trade-off" coefficient is about 1.2 percentage points. The corresponding long-run coefficient is (estimate of  $a_4$ )/(1 - estimate of  $a_7$ ) =  $0.0116/(1 - 0.5477) = 0.0256$  or about 2.6 percentage points.
  8. The figures in parentheses are absolute values of the t-ratio. This is the case throughout this chapter unless otherwise stated.  $\bar{R}^2$  denotes the adjusted coefficient of multiple determination and D - W the Durbin-Watson statistic.

$$w = \begin{matrix} -2.892 & + & 15.467u^{-1} & + & 0.233\dot{Y} & + & 0.476p_t^e(1.0) \\ (1.57) & & (3.40) & & (3.53) & & (2.08) \end{matrix}$$

$$\bar{R}^2 = 0.784$$

D-W not given

As was the case with Solow's results, the value of  $\gamma$  implicit in Toyoda's preferred equation is  $\gamma = 1.0$  which corresponds to the case in which  $p_t^e = p_{t-1}$ . Toyoda's preferred equation implies that in the short-run a one point increase in the unemployment rate will lead to a decrease in the rate of wage-inflation of about 6.9 points at an unemployment rate of 1.5 per cent or about 3.9 points at an unemployment rate of 2.0 per cent.<sup>9</sup> Furthermore, there is a considerable long-run trade-off, a one point increase in the unemployment rate implying a decrease in the rate of wage-inflation of about 13.1 points at an unemployment rate of 1.5 per cent or about 7.4 points at an unemployment rate of 2.0 per cent in the long-run.<sup>10</sup>

Vanderkamp's [136] examination of the expectations hypothesis for the Canadian economy is also based on the PE approach. Unlike Solow and Toyoda, however, Vanderkamp considers two different distributed lag expectations formation schemes, one with geometrically declining weights<sup>11</sup> and the other with weights which decline linearly.

9. From the Toyoda preferred equation  $\partial w / \partial u = -15.467u^{-2} = -6.874$  when  $u = 1.5$  and  $-3.867$  when  $u = 2.0$ .

10. The long-run Phillips curve implied by Toyoda's preferred equation is  $w = 29.517u^{-1} + 0.445\dot{Y}$  from which it follows that  $\partial w / \partial u = -29.517u^{-2}$  which is  $-13.119$  when  $u = 1.5$  and  $-7.379$  when  $u = 2.0$ .

11. The adaptive scheme is equivalent to a distributed lag on  $p$  with geometrically declining weights but its form differs from the distributed lag considered by Vanderkamp. See below, p. 209.

In both cases the weights sum to unity. The schemes in question are

$$p_t^e = (1 - \lambda)p_t + (1 - \lambda)\lambda p_{t-1} + (1 - \lambda)\lambda^2 p_{t-2} + \dots \quad (3.5)$$

and

$$p_t^e = \frac{2n}{n(n+1)} p_t + \frac{2(n-1)}{n(n+1)} p_{t-1} + \frac{2(n-2)}{n(n+1)} p_{t-2} + \dots \\ \dots + \frac{2}{n(n+1)} p_{t-n+1} \quad (3.6)$$

Proxy series for the expected rate of inflation can be generated from (3.5) for various values of  $\lambda$  (bearing in mind that  $0 \leq \lambda \leq 1$ ) and from (3.6) for various integer values of  $n$ . In the case of (3.5) it is necessary to truncate the infinite distributed lag at some finite number of terms and to supply an initial value for  $p^e$ . Unfortunately Vanderkamp gives no indication of the initial value he used although he states that (3.5) was truncated at the tenth term. Vanderkamp generated proxy  $p^e$  series from (3.5) corresponding to  $\lambda = 0.4, 0.5, 0.6, 0.7$  and  $0.8$  and from (3.6) corresponding to  $n = 1, 2, 3, \dots, 9, 10$ . In keeping with the notation adopted previously these proxied expectations series can be denoted by  $p_t^e(\lambda)$  and  $p_t^e(n)$ . All told there were fifteen such series.

Vanderkamp considered two wage equations, namely:

$$w_t = a_0 + a_1 v_t + a_2 (v_t - v_{t-1}) + a_3 R_t + a_4 p_t^e \quad (3.7)$$

$$w_t = b_0 + b_1 u_t^{-1} + b_2 (u_t^{-1} - u_{t-1}^{-1}) + b_3 R_t + b_4 p_t^e \quad (3.8)$$

where  $v$  denotes job vacancies as a percentage of the labour force and  $R$  total output per employed person expressed as percentage deviations from trend. Using quarterly Canadian data for the period 1949 to 1968,

Vanderkamp estimated both (3.7) and (3.8) using OLS for each of the fifteen proxy  $p^e$  series described above. Selecting those equations which produce the highest value of  $R^2$ , he found that for both (3.7) and (3.8) the preferred proxy  $p^e$  series were  $p_t^e(n = 6)$  and  $p_t^e(\lambda = 0.7)$ . The corresponding preferred estimations of (3.7) after correcting for first-order autocorrelation (albeit in a very crude way) were respectively

$$w_t = \begin{matrix} 1.492 & + & 1.377v_t & + & 4.891(v_t - v_{t-1}) & + & 0.356R_t & + & 0.771p_t^e(n=6) \\ (2.618) & & (2.416) & & (3.797) & & (4.395) & & (9.071) \end{matrix}$$

$$R^2 = 0.786 \quad D-W = 1.857$$

$$w_t = \begin{matrix} 1.841 & + & 0.736v_t & + & 5.291(v_t - v_{t-1}) & + & 0.414R_t & + & 0.922p_t^e(\lambda = 0.7) \\ (3.105) & & (1.174) & & (4.048) & & (4.871) & & (8.951) \end{matrix}$$

$$R^2 = 0.784 \quad D-W = 1.847$$

while those for (3.8) were respectively

$$w_t = \begin{matrix} 1.967 & + & 2.652u_t^{-1} & + & 11.801(u_t^{-1} - u_{t-1}^{-1}) & + & 0.350R_t & + & 0.776p_t^e(n=6) \\ (3.649) & & (1.864) & & (3.062) & & (3.933) & & (9.463) \end{matrix}$$

$$R^2 = 0.751 \quad D-W = 1.917$$

$$w_t = \begin{matrix} 2.376 & + & 0.715u_t^{-1} & + & 12.208(u_t^{-1} - u_{t-1}^{-1}) & + & 0.426R_t & + & 0.935p_t^e(\lambda = 0.7) \\ (4.304) & & (0.461) & & (3.185) & & (4.630) & & (9.541) \end{matrix}$$

$$R^2 = 0.754 \quad D-W = 1.914$$

Vanderkamp's four preferred equations are quite similar and, for this reason, only the two relating to (3.8) will be considered further.

In both the preferred estimations of (3.8) the coefficient of  $p^e$  is quite high. However when the proxy  $p^e$  series is generated using (3.6) the coefficient of  $p^e$  is significantly different from unity at the 1 per cent level while that coefficient is not significantly different

from unity even at 10 per cent in the case in which (3.5) is the basis for the generation of the proxy  $p^e$  series. This being so it is not possible to draw from Vanderkamp's results any strong conclusion regarding the existence of a long-run trade-off between unemployment and the rate of wage-inflation. The preferred estimations are likewise inconsistent with regard to the severity of the short-run trade-off. The estimates of the coefficient of  $u^{-1}$  are 2.652 for the case in which (3.6) is the basis for the proxy  $p^e$  series and 0.715 when this basis is (3.5). The considerable difference in these point estimates illustrates the sensitivity of the parameter estimates to the specification of the expectations formation equation.

### 3.3 Studies Based on the RF Approach

The study undertaken by Parkin [89] for the United Kingdom is based on the Reduced Form (RF) approach and represents an excellent vehicle for explaining its main characteristics. Parkin's model is a version of prototype Model A.2, namely:

$$w_t = \alpha + \beta u_t + \delta p_t^e \quad (3.9)$$

$$p_t^e = \gamma p_t + (1 - \gamma)p_{t-1}^e \quad (3.10)$$

The expectations formation equation (3.10) is, of course, just the adaptive scheme. The reduced form equation for  $w_t$  in this two equation system can be obtained by substituting (3.10) in (3.9), the result being:

$$w_t = \alpha + \beta u_t + \gamma \delta p_t + (1 - \gamma) \delta p_{t-1}^e \quad (3.11)$$

This reduced form equation can then be rephrased so that it runs entirely in terms of observables as follows. From (3.9),

$$\delta p_t^e = w_t - \alpha - \beta u_t$$

from which it follows immediately that

$$(1 - \gamma)\delta p_{t-1}^e = (1 - \gamma)w_{t-1} - \alpha(1 - \gamma) - \beta(1 - \gamma)u_{t-1} \quad (3.12)$$

Substitution of (3.12) in (3.11) produces

$$w_t = \alpha + \beta u_t + \gamma \delta p_t + (1 - \gamma)w_{t-1} - \alpha(1 - \gamma) - \beta(1 - \gamma)u_{t-1}$$

Rearranging,

$$w_t = \alpha\gamma + \beta u_t - \beta(1 - \gamma)u_{t-1} + \gamma \delta p_t + (1 - \gamma)w_{t-1} \quad (3.13)$$

which can be written

$$w_t = a_1 + a_2 u_t + a_3 u_{t-1} + a_4 p_t + a_5 w_{t-1} \quad (3.14)$$

where  $a_1 = \alpha\gamma$

$a_4 = \gamma\delta$

$a_2 = \beta$

$a_5 = 1 - \gamma$

$a_3 = -\beta(1 - \gamma)$

Equation (3.13) or equivalently (3.14) was estimated by Parkin using non-linear constrained least squares and quarterly data for the

United Kingdom for the period 1950(4) to 1955(4) and 1957(1) to 1961(2).<sup>12</sup>

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12. This equation is in fact only one of a number of related equations estimated by Parkin as part of a study of the effects of incomes policy on the relationship between unemployment and wage-inflation. The sample period reported is the "policy-off" sample period and Parkin's estimates appear in his Table 2 [89, p. 390].



After applying a correction for first-order autocorrelation, Parkin obtained the following estimates of the structural parameters appearing in (3.9) and (3.10)<sup>13</sup>

$$\begin{array}{cccc} \hat{\alpha} = 7.283 & \hat{\beta} = -2.629 & \hat{\delta} = 0.421 & \hat{\gamma} = 0.609 \\ (3.947) & (2.626) & (3.315) & (2.819) \end{array}$$

These estimates indicate that the short-run trade-off between unemployment and wage-inflation is quite appreciable and that a non-degenerate long-run trade-off exists. In the short-run, a one point increase in the unemployment rate will lead to a decrease of about 2.6 percentage points in the rate of wage-inflation at all unemployment rates. The long-run Phillips curve implied by the estimates reported is

$$w_t = 12.579 - 4.541u_t$$

indicating that a one point increase in the unemployment rate will lead to a decrease of about 4.5 percentage points in the rate of wage-inflation in the long-run.

As part of an examination of several versions of the Phillips curve for Canada, Donner and Lazar [20] examined models of the form of the prototype models B.1 and A.2 using the RF approach. The first of these is the following.

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + w_t^e \quad (3.15)$$

$$w_t^e = w_{t-1} + \lambda(w_{t-1} - w_{t-1}^e) \quad (3.16)$$

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13. Figures in parentheses are absolute values of the asymptotic t-ratios.  $\hat{\alpha}$  denotes estimate of  $\alpha$  and so on.

(3.15) is the wage equation of Model B.1 with  $f(u_t) = \alpha_0 + \alpha_1 u_t^{-1}$ .

(3.16) is the adaptive scheme with coefficient  $(1 + \lambda)$ .<sup>14</sup> Proceeding in the manner described above, the following expression for the reduced form equation for  $w_t$  implied by (3.15) and (3.16) can be obtained.

$$w_t = \alpha_0(1 + \lambda) + \alpha_1 u_t^{-1} + \alpha_1 \lambda u_{t-1}^{-1} + w_{t-1} \quad (3.17)$$

or

$$w_t - w_{t-1} = \alpha_0(1 + \lambda) + \alpha_1 u_t^{-1} + \alpha_1 \lambda u_{t-1}^{-1} \quad (3.18)$$

which is the form estimated by Donner and Lazar.<sup>15</sup> Using quarterly data for Canada for the period 1955(1) to 1970(3) and the OLS estimator, they obtained the following estimated form of (3.18).

$$w_t - w_{t-1} = \underset{(1.27)}{-0.465} + \underset{(3.29)}{22.612} u_t^{-1} - \underset{(2.88)}{19.859} u_{t-1}^{-1}$$

$$\bar{R}^2 = 0.14 \quad D-W = 2.89$$

These results imply that in the short-run a one point increase in the unemployment rate will lead to a decrease of about 2.5 percentage points in the rate of wage-inflation when the unemployment rate is 3 per cent or about 0.9 percentage points when the unemployment rate is 5 per cent. The possibility of a long-run trade-off between unemployment and wage-inflation is, of course, excluded by virtue of the specification of the model,  $w_t^e$  entering (3.15) with a unitary

14. (3.16) can be rewritten as  $w_t^e - w_{t-1}^e = (1 + \lambda)[w_{t-1} - w_{t-1}^e]$ .

15. Certain errors in Donner and Lazar's algebra have been corrected.

coefficient. In these circumstances there is a natural rate of unemployment, the estimate of which implied by the estimated form of (3.18) is 5.9 per cent.<sup>16</sup>

The second expectations-hypothesis model considered by Donner and Lazar is of the form of Model A.2, namely:

$$w_t = \beta_0 + \beta_1 u_t^{-1} + \delta p_t^e \quad (3.19)$$

$$p_t^e = p_{t-1} + \eta(p_{t-1} - p_{t-1}^e) \quad (3.20)$$

In this case, the RF approach leads to the following equation for estimation.<sup>17</sup>

$$w_t = \beta_0(1 + \eta) + \beta_1 u_t^{-1} + \beta_1 \eta u_{t-1}^{-1} + \delta(1 + \eta)p_{t-1} - \eta w_{t-1} \quad (3.21)$$

Donner and Lazar's OLS estimation of (3.21) is

$$w_t = -0.360 + 23.55u_t^{-1} - 18.713u_{t-1}^{-1} + 0.265p_{t-1} + 0.756w_{t-1}$$

(1.01)      (3.13)      (2.34)      (2.09)      (7.94)

$R^2 = 0.89$       D-W = 2.51

The short-run trade-off between unemployment and wage-inflation implied by the estimated form of (3.21) is very similar indeed to that discussed earlier with reference to (3.18) and need not be considered

16. A formula for the natural rate of unemployment ( $u^*$ ) can be obtained from (3.18). In the long-run or steady state,  $w_t = w_{t-1}$  and  $u_t = u_{t-1}$ . Substituting these into (3.18) we get  $\alpha_0(1 + \lambda) + \alpha_1(1 + \lambda)u^{-1} = 0$ . The natural rate of unemployment is the solution to this equation, hence  $(u^*)^{-1} = -\alpha_0(1 + \lambda)/(\alpha_1 + \alpha_1\lambda)$ . The estimates of  $\alpha_0(1 + \lambda)$ ,  $\alpha_1$  and  $\alpha_1\lambda$  are respectively -0.465, 22.612 and -19.859 implying an estimate of  $u^*$  of 5.92.

17. Here again (3.21) does not correspond exactly to Donner and Lazar's expression which contains certain derivation errors.

further. Unlike (3.18), (3.21) implies the existence of a long-run trade-off. However, in view of the over-identification of the structural parameters<sup>18</sup> in (3.21), it is not possible to extract a unique estimate of  $\delta$  from the OLS estimates of the reduced form coefficients of (3.21) and it is therefore not possible to obtain an expression for the implied long-run Phillips curve.

Another Canadian study which employs the RF approach<sup>19</sup> is that by Turnovsky [131]. Turnovsky considers two expectations-hypothesis models, namely versions of prototype models A.2 and B.2. In each case three different specifications of the expectations formation equation were tried; a first-order extrapolative scheme

$$p_t^e = p_t + \theta(p_t - p_{t-1}) \quad (3.22)$$

a first-order adaptive scheme<sup>20</sup>

$$p_t^e = p_{t-1}^e + \gamma(p_t - p_{t-1}^e) \quad (3.23)$$

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18. See below, p. 115.

19. In the same study Turnovsky makes use of the OE approach. This part of his study will be considered in section 3.4.

20. Note that Turnovsky's specification of the first-order adaptive scheme differs from the one considered in Chapter Two in that  $p_t$  appears in place of  $p_{t-1}$  on the right-hand side of (3.23). This difference can be rationalized in terms of the interpretation placed on  $p_t^e$ . In Chapter Two and throughout this thesis,  $p_t^e$  is the expectation formed *during* period  $t$  about the rate of inflation in period  $t+1$ . Implicit in Turnovsky's specification of the adaptive scheme is that  $p_t^e$  is the expectation formed *at the time instant* marking the end of period  $(t-1)$  or the beginning of period  $t$  about the rate of inflation in period  $t$ . For precisely the same reason (3.22) is a different specification of the first-order extrapolative scheme from that which is used in Chapter Four below.

and a more general distributed lag scheme

$$p_t^e = \sum_{i=0}^n \lambda_i p_{t-i} \quad \text{with} \quad \sum_{i=0}^n \lambda_i = 1 \quad (3.24)$$

The first wage equation considered was of the form of prototype Model A.2, namely:

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + \delta p_t^e \quad (3.25)$$

Using the RF approach to combine (3.25) with the extrapolative scheme (3.22) we get

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + \delta p_t + \delta \theta (p_t - p_{t-1}) \quad (3.26)$$

while combining (3.25) with the adaptive scheme (3.23) we obtain

$$w_t = \alpha_0 \gamma + \alpha_1 u_t^{-1} - \alpha_1 (1 - \gamma) u_{t-1}^{-1} + \delta \gamma p_t + (1 - \gamma) w_{t-1} \quad (3.27)$$

Finally, combining (3.25) with the distributed lag scheme (3.24) by means of the RF approach we find that

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + \delta \sum_{i=0}^n \lambda_i p_{t-i} \quad (3.28)$$

Turnovsky estimated each of (3.26), (3.27) and (3.28) using OLS and half-yearly Canadian data for the period 1949 to 1969. The intercept was suppressed whenever it was found to be statistically insignificant. In the case of (3.23), Turnovsky reports two sets of estimates. The first of these results from estimating (3.28) freely with  $n = 3$  while the second results from the estimation of an Almon [1] lag using a second-degree polynomial with  $n = 3$ . Turnovsky's results are as follows with the equation from which the estimates derive being shown on the left-hand side.

$$(3.26) \quad w_t = \frac{13.874}{(12.508)} u_t^{-1} + \frac{0.773}{(9.137)} p_t - \frac{0.393}{(5.261)} (p_t - p_{t-1})$$

$$\bar{R}^2 = 0.879 \quad D-W = 1.57$$

$$(3.27) \quad w_t = \frac{12.968}{(6.189)} u_t^{-1} - \frac{5.834}{(1.918)} u_t^{-1} + \frac{0.507}{(6.624)} p_t + \frac{0.448}{(4.559)} w_{t-1}$$

$$\bar{R}^2 = 0.876 \quad D-W = 2.62$$

$$(3.28) \quad w_t = \frac{11.924}{(8.160)} u_t^{-1} + \frac{0.478}{(5.127)} p_t + \frac{0.316}{(3.580)} p_{t-1} + \frac{0.065}{(0.742)} p_{t-2} + \frac{0.120}{(1.406)} p_{t-3}$$

$$\bar{R}^2 = 0.886 \quad D-W = 1.73$$

$$(3.28) \quad w_t = \frac{12.451}{(10.191)} u_t^{-1} + \frac{0.458}{(8.143)} p_t + \frac{0.278}{(9.132)} p_{t-1} + \frac{0.142}{(4.371)} p_{t-2} + \frac{0.049}{(1.893)} p_{t-3}$$

$$\bar{R}^2 = 0.890 \quad D-W = 1.69$$

The general quality of these estimates is extremely good. In addition, the four sets of estimates are consistent as regards the severity of the short-run trade-off between unemployment and wage-inflation, the estimate of the coefficient of  $u_t^{-1}$  varying from 11.924 to 13.874 with a high  $t$ -ratio in every case. The estimate of this coefficient from the OLS estimation of (3.27) is, for instance, 12.968, implying that in the short-run a one point increase in the unemployment rate will lead to a reduction in the rate of wage-inflation of about 5.8 percentage points at an unemployment rate of 1.5 per cent, about 3.2 points at 2.0 per cent unemployment or about 1.4 points at 3.0 per cent unemployment. The coefficient ( $\delta$ ) of the expected rate of inflation in the wage equation (3.25) can be identified in (3.26) and (3.27) but not in (3.28). The estimate of  $\delta$  implied by the estimation of (3.26) is 0.773 while that implied by the estimation

of (3.27) is<sup>21</sup> 0.918. Turnovsky concludes on the basis of these estimates (perhaps without being fully justified in doing so) that there is no long-run trade-off between unemployment and wage-inflation, the true coefficient of the expected rate of inflation in the wage equation being unity.

The second wage equation considered by Turnovsky is a form of the wage equation which appears in prototype Model B.2, namely:

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + \alpha_2 u_{t-1}^{-1} + \delta w_t^e \quad (3.29)$$

The expectations formation schemes considered in this case are

$$w_t^e = w_{t-1} + \theta(w_{t-1} - w_{t-2}) \quad (3.30)$$

$$w_t^e = w_{t-1} \quad (3.31)$$

$$w_t^e = \sum_{i=0}^n \lambda_i w_{t-i} \quad \text{with} \quad \sum_{i=0}^n \lambda_i = 1 \quad (3.32)$$

(3.30) and (3.32) are respectively a conventional extrapolative scheme<sup>22</sup> and a general distributed lag scheme analogous to (3.24).

(3.31) is the case of static expectations and is used in this instance instead of the adaptive scheme.<sup>23</sup> Using the RF approach to combine each of these individually with the wage equation (3.29) we obtain

21.  $\delta = \text{coefficient of } p_t \div (1 - \text{coefficient of } w_{t-1}) = \delta\gamma/[1 - (1-\gamma)]$ . The estimate of the coefficient of  $p_t$  is 0.507 while that for  $w_{t-1}$  is 0.448.

22. Note that the conventional specification of the extrapolative scheme (3.30) is inconsistent with the interpretations of  $w_t^e$  and  $p_t^e$  implicit in all of Turnovsky's other expectations formation schemes. See above, p. 83n.

23. See Turnovsky [131, p. 9].

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + \alpha_2 u_{t-1}^{-1} + \delta w_{t-1} + \theta \delta (w_{t-1} - w_{t-2}) \quad (3.34)$$

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + \alpha_2 u_{t-1}^{-1} + \delta w_{t-1} \quad (3.35)$$

$$w_t = \alpha_0 + \alpha_1 u_t^{-1} + \alpha_2 u_{t-1}^{-1} + \delta \sum_{i=0}^n \lambda_i w_{t-i} \quad (3.36)$$

These three equations were also estimated by Turnovsky using OLS.

However, on this occasion he presents only one estimate of (3.36),

that for which  $n = 3$  and the coefficients are estimated freely.

The three estimated equations are as follows, the underlying equation in question again being indicated on the left-hand side.

$$(3.34) \quad w_t = \frac{20.405 u_t^{-1}}{(6.326)^t} - \frac{9.445 u_{t-1}^{-1}}{(2.178)^{t-1}} + \frac{0.513 w_{t-1}}{(3.868)^{t-1}} + \frac{0.242 (w_{t-1} - w_{t-2})}{(2.253)^{t-1}}$$

$$\bar{R}^2 = 0.750 \quad D-W = 2.41$$

$$(3.35) \quad w_t = \frac{-1.018}{(1.342)} + \frac{20.210 u_t^{-1}}{(6.467)^t} - \frac{5.754 u_{t-1}^{-1}}{(1.252)^{t-1}} + \frac{0.538 w_{t-1}}{(3.973)^{t-1}}$$

$$\bar{R}^2 = 0.733 \quad D-W = 1.74$$

$$(3.36) \quad w_t = \frac{20.314 u_t^{-1}}{(6.377)^t} - \frac{7.643 u_{t-1}^{-1}}{(1.666)^{t-1}} + \frac{0.665 w_{t-1}}{(4.024)^{t-1}} - \frac{0.073 w_{t-2}}{(0.494)^{t-2}} - \frac{0.175 w_{t-3}}{(1.560)^{t-3}}$$

$$\bar{R}^2 = 0.750 \quad D-W = 2.33$$

Turnovsky's view is that the main feature of these results is that they are statistically inferior to the earlier set, indicating that Model A.2 is most likely to be more appropriate for Canada than Model B.2. There is again marked consistency among the estimations with regard to the severity of the short-run trade-off between unemployment and wage-inflation, it being somewhat steeper than in the earlier case. For instance, at an unemployment rate of 2.0 per cent, the estimation of (3.35) implies that in the short-run a one point increase in the unemployment rate will bring forth a reduction of about 5.1 points



in the rate of wage-inflation. The corresponding figure for Turnovsky's first model was 3.2 points. The implied value of the coefficient ( $\delta$ ) of the expected rate of wage-inflation in the wage equation (3.29) is 0.513 for the expectations formation scheme (3.30) and 0.538 for (3.31). As before, it is not possible to identify this coefficient in the case of (3.32). The estimates suggest a long-run unemployment-wage-inflation trade-off which is a good deal flatter than was the case with the earlier models. However, as has already been noted, in view of the poorer performance of these models when compared to the earlier ones, little weight can be given to this conclusion.

Turnovsky and Wachter [134] also used the RF approach in an examination of the expectations-hypothesis for the United States economy.<sup>24</sup> The Turnovsky-Wachter study will be considered only briefly at this stage since it bears quite a strong resemblance to the Turnovsky [131] study discussed above and since the RF approach played no more than a relatively minor part. Among the various models considered by Turnovsky and Wachter were the prototype models A.2 and B.2. In the case of Model A.2 three different expectations formation schemes were considered - the first-order extrapolative scheme, the first-order adaptive scheme and the general distributed lag scheme, specified in each case in the same way as in Turnovsky [131].<sup>25</sup> Only one expectations formation scheme was considered in conjunction with Model B.2, this being the adaptive scheme. The estimating equations were arrived at in the

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24. Like Turnovsky [131], Turnovsky and Wachter undertook essentially the same exercise using the OE approach. This part of their study will be considered in section 3.4 below.

25. See above, pp. 83-4.

usual way using the RF approach in each case. Estimation was performed by OLS using half-yearly data for the United States over the period 1949 to 1969. Turnovsky and Wachter's results are as follows.

*Model A.2, Extrapolative Scheme*

$$w_t = \frac{1.432}{(1.836)} + \frac{13.320u^{-1}}{(3.781)t} + \frac{0.427p}{(3.813)t} + \frac{0.153(p_t - p_{t-1})}{(1.298)t} - \frac{2.509d}{(6.706)t}$$

$$\bar{R}^2 = 0.714 \quad D-W = 1.49$$

(3.37)

*Model A.2, Adaptive Scheme*

$$w_t = \frac{1.610}{(1.835)} + \frac{21.914u^{-1}}{(3.326)t} - \frac{10.209u^{-1}}{(1.719)t^{-1}} + \frac{0.493p}{(4.521)t} - \frac{0.021w}{(0.137)t^{-1}} - \frac{2.364d}{(4.875)t}$$

$$\bar{R}^2 = 0.716 \quad D-W = 1.47$$

(3.38)

*Model A.2, General Distributed Lag Scheme (n = 3)*

$$w_t = \frac{1.199}{(1.633)} + \frac{14.556u^{-1}}{(4.086)t} + \frac{0.466p}{(3.879)t} + \frac{0.143p}{(0.954)t^{-1}} - \frac{0.354p}{(2.569)t^{-2}} + \frac{0.129p}{(1.109)t^{-3}} - \frac{2.417d}{(3.797)t}$$

$$\bar{R}^2 = 0.750 \quad D-W = 1.43$$

(3.39)

*Model B.2, Adaptive Scheme*

$$w_t = \frac{2.708}{(2.572)} + \frac{25.763u^{-1}}{(3.284)t} - \frac{17.367u^{-1}}{(2.555)t^{-1}} + \frac{0.244w}{(1.476)t^{-1}} - \frac{2.924d}{(5.135)t}$$

$$\bar{R}^2 = 0.568 \quad D-W = 1.39$$

(3.40)

In the above equations,  $d$  is a seasonal dummy variable. Turnovsky and Wachter look upon (3.39) as the best of these four estimations. This estimation implies that in the short-run a one point increase in the unemployment rate will lead to a reduction of about 3.6 percentage points in the rate of wage-inflation at an unemployment rate of 2.0 per cent. At 4.0 per cent unemployment the figure is about 0.9 percentage points. The existence of a long-run trade-off is confirmed by (3.39). It is not possible to comment on its severity, however, because the required parameter, the coefficient of the expected rate of inflation in the wage equation, cannot be identified in (3.39).<sup>26</sup> The required parameter can be identified in (3.37) as the coefficient of  $p_t$  and in (3.38) as the coefficient of  $p_t$  divided by unity minus the coefficient of  $w_{t-1}$ .<sup>27</sup> The implied coefficient ( $\delta$ ) of the expected rate of inflation in the wage equation is 0.427 in the case of (3.37) and 0.483 in the case of (3.38). However in view of the fact that the estimated coefficient of  $w_{t-1}$  in (3.38) has the wrong *a priori* sign<sup>28</sup> the latter estimate of  $\delta$  should be viewed with caution. Be that as it may, it appears from the estimate arising from (3.37) that there is a quite considerable non-degenerate long-run trade-off between unemployment and wage-inflation in the case of the United States.

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26. See equation (3.28) above which is of precisely the same form as that underlying (3.39).

27. These remarks follow from the fact that the equations which underly (3.37) and (3.38) are of the same form as (3.26) and (3.27) respectively.

28. From (3.27), the coefficient of  $w_{t-1}$  in the equation which underlies (3.37) is  $(1 - \gamma)$ . As  $\gamma$  satisfies  $0 \leq \gamma \leq 1$ , it can be expected *a priori* that the coefficient of  $w_{t-1}$  in (3.37) will be non-negative.

### 3.4 Studies Based on the OE Approach

The Observed Expectations (OE) approach is the most straightforward method of handling the expectations variables, at least from an econometric point of view. However, because the required data are not often available, it has not frequently been used. As far as the prototype models are concerned only two studies have been based on the OE approach. The studies in question were both considered with reference to their use of the RF approach in the previous section. They are Turnovsky and Wachter [134] for the United States and Turnovsky [131] for Canada. As its name suggests the chief characteristic of the OE approach is the use of an actually observed series for the expectations variable.

The basis for the observed expectations series used by Turnovsky and Wachter [134] was the biannual survey conducted by J. A. Livingston, the financial editor of the *Philadelphia Bulletin*. Each June and December, Livingston asked a group of between forty and sixty business, government and academic economists their predictions, for the next six months and for the next twelve months, of several economic series for the United States. Among these series were the Consumer Price Index and the Average Weekly Wages in Manufacturing. In each case Livingston published an average of the predictions. Turnovsky and Wachter interpreted the rate of change of the Livingston prediction of the Consumer Price Index as the expected rate of inflation and the rate of change of the Livingston prediction of the Average Weekly Wages in Manufacturing as the expected rate of wage-inflation. Having placed this interpretation on the Livingston predictions, they were then able

to estimate the wage equation of any of the prototype models directly, using quite conventional econometric methods. Unfortunately, Turnovsky and Wachter did not report any such estimates of the wage equations of Models A.2 and B.2, the two prototype models which they considered. What they did report however, is the estimation of the following closely related wage equation.

$$w_t = a_0 + a_1 u_t^{-1} + \delta p_t^e + \eta(p_t - p_{t-1}^e) \quad (3.41)$$

The final term,  $(p_t - p_{t-1}^e)$  is described by Turnovsky and Wachter as a "catch-up" term. It is included on the grounds that when the actual rate of inflation exceeds the rate that was expected for the quarter in question an adjustment will be made to wages to correct for this forecasting error. Thus (3.41) is the wage equation of Model A.2 modified to take account of the catch-up effect. Turnovsky and Wachter also report the estimates of the following wage equation of the form of Model B.2, modified to capture the catch-up effect.

$$w_t = a_0 + a_1 u_t^{-1} + \delta w_t^e + \eta(w_{t-1} - w_{t-1}^e) \quad (3.42)$$

The estimated form of (3.41) is

$$w_t = 0.978 + 15.918 u_t^{-1} + 0.240 p_t^e + 0.480(p_t - p_{t-1}^e) - 2.528 d_t \quad (1.372) \quad (5.224) \quad (2.343) \quad (6.326) \quad (7.438)$$

$$\bar{R}^2 = 0.762 \quad D-W = 1.69$$

and that of (3.42) is

$$w_t = 1.619 + 12.239 u_t^{-1} + 0.314 w_t^e + 0.413(w_{t-1} - w_{t-1}^e) - 3.246 d_t \quad (1.881) \quad (2.966) \quad (2.550) \quad (4.079) \quad (6.879)$$

$$\bar{R}^2 = 0.643 \quad D-W = 1.56$$

$d_t$  is again a seasonal dummy variable. In the long-run or steady state  $p_t = p_{t-1} = p_{t-1}^e$  and  $w_{t-1} = w_{t-1}^e$  which means that the "catch-up" term disappears in each case and the long-run implications of the modified wage equations (3.41) and (3.42) are the same as those which apply to the corresponding prototype wage equations. In particular, both estimations suggest that there is a considerable long-run trade-off between unemployment and wage-inflation in the United States. This is the case because the coefficients of the expected rate of inflation and the expected rate of wage-inflation in the respective wage-equations are of the order of 0.3 and are significantly smaller than unity at the 1 per cent level of significance.<sup>29</sup>

The OE approach also formed the basis for part of Turnovsky's [131] study of the expectations hypothesis with reference to the Canadian economy. However, there being no available observed expectations series for Canada, Turnovsky used the Livingston series for the United States as proxies for the corresponding Canadian expectations. His justification for doing so rests on "... the overall similarities in price and wage movements which have occurred in the two countries over the post-war period ... [,] the close dependence of the Canadian on the American economy ... [and] the direct linkages between the two countries..." [131, p. 2]

Turnovsky considered wage equations of the form of prototype models A.2 and B.2. In each case he tried two separate versions, one with  $f(u_t)$  replaced by  $(a_0 + a_1 u_t^{-1})$  and the other with

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29. The observed value of  $(\hat{\delta} - 1)/\hat{\sigma}_{\hat{\delta}}$  is 7.422 in the case of the estimated form of (3.41) and 5.572 for (3.42). The rejection region for  $H_0: \delta = 1$  against  $H_1: \delta < 1$  at the 1 per cent level is  $t \leq -2.326$  and  $t \geq 2.326$ .

$(a_0 + a_1 u_t^{-1} + a_2 u_{t-1}^{-1})$  replacing  $f(u_t)$ . The resulting four wage equations were each estimated twice. In the first of these the expectations variable in question was proxied by the appropriate Livingston prediction for the next six months<sup>30</sup> while in the second the proxy for the relevant expectations variable was the appropriate Livingston prediction for the next twelve months.

Denoting the expectation of the rate of inflation formed at  $t$  for the next six months by  $p_{6,t}^e$  and the expectation of the rate of inflation formed at  $t$  for the next twelve months by  $p_{12,t}^e$ , Turnovsky's estimates of the wage equation of prototype model A.2, obtained by applying OLS to half-yearly Canadian data for the period 1949 to 1969, are as follows.

$$w_t = -1.137 + 22.396u_t^{-1} + 0.768p_{6,t}^e$$

$$(2.059) \quad (10.698) \quad (7.083)$$

$$\bar{R}^2 = 0.823 \quad D-W = 1.76 \quad (3.43)$$

$$w_t = -1.752 + 19.025u_t^{-1} + 6.037u_{t-1}^{-1} + 0.743p_{6,t}^e$$

$$(3.081) \quad (8.072) \quad (2.554) \quad (7.310)$$

$$\bar{R}^2 = 0.846 \quad D-W = 1.58 \quad (3.44)$$

$$w_t = -1.597 + 24.373u_t^{-1} + 0.876p_{12,t}^e$$

$$(2.615) \quad (10.879) \quad (6.186)$$

$$\bar{R}^2 = 0.795 \quad D-W = 1.71 \quad (3.45)$$

$$w_t = -2.345 + 20.254u_t^{-1} + 7.254u_{t-1}^{-1} + 0.865p_{12,t}^e$$

$$(3.832) \quad (8.178) \quad (2.934) \quad (6.709)$$

$$\bar{R}^2 = 0.830 \quad D-W = 1.43 \quad (3.46)$$

Turnovsky rates as the main features of these estimations the fact that in all cases the expectations variable is strongly significant,

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30. See above, p. 91.

that the magnitudes of their coefficients are consistent with the values he obtained using the RF approach<sup>31</sup> and that they are "... basically consistent with neo-classical [accelerationist] theory of the labour market." [131, p. 14] The last point is justified in the case of the twelve month expectations because in neither of these is the coefficient ( $\delta$ ) of the expected rate of inflation significantly smaller than unity.<sup>32</sup> However, in the case of the six month expectations the coefficient ( $\delta$ ) of the expected rate of inflation is significantly smaller than unity at the 5 per cent level.<sup>33</sup>

Turnovsky's estimates of the wage equation of prototype model B.2 are as follows, with  $w_{6,t}^e$  and  $w_{12,t}^e$  denoting the expectations formed at  $t$  for the rate of wage-inflation over the next six and twelve months respectively.

$$w_t = -1.124 + 20.508u_t^{-1} + 0.433w_{6,t}^e$$

$$(1.528) \quad (7.055) \quad (3.632)$$

$$\bar{R}^2 = 0.693 \quad D-W = 1.21 \quad (3.47)$$

$$w_t = -1.700 + 17.437u_t^{-1} + 5.907u_{t-1}^{-1} + 0.398w_{6,t}^e$$

$$(2.174) \quad (5.293) \quad (1.806) \quad (3.399)$$

$$\bar{R}^2 = 0.710 \quad D-W = 1.02 \quad (3.48)$$

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31. See above, p. 85.

32. In (3.45),  $(\hat{\delta} - 1)/\hat{\sigma}_{\hat{\delta}}$  equals -0.876 while in (3.46) it equals -1.047. The rejection region for  $H_0: \delta = 1$  against  $H_1: \delta < 1$  at the 5 per cent level is  $t \leq -1.645$  and  $t \geq +1.645$ . Thus for each of (3.45) and (3.46) acceptance of the null hypothesis  $\delta = 1$  is indicated.

33.  $(\hat{\delta} - 1)/\hat{\sigma}_{\hat{\delta}}$  equals -2.140 in (3.43) and -2.528 in (3.44). Using the usual test, rejection of the null hypothesis  $\delta = 1$  is indicated.



$$w_t = \frac{-1.563}{(2.368)} + \frac{20.649u_t^{-1}}{(8.276)} + \frac{0.622w_{12,t}^e}{(5.280)} \quad \bar{R}^2 = 0.762 \quad D-W = 1.45 \quad (3.49)$$

$$w_t = \frac{-2.073}{(2.987)} + \frac{17.783u_t^{-1}}{(6.228)} + \frac{5.384u_t^{-1}}{(1.879)} + \frac{0.625w_{12,t}^e}{(5.087)} \quad \bar{R}^2 = 0.777 \quad D-W = 1.23 \quad (3.50)$$

Turnovsky considers this set of estimations to be statistically inferior to the set of estimations of prototype model B.2 reported above. One of their main deficiencies in his view is that, while significantly different from zero, the coefficient of the expected rate of wage-inflation is well below unity in every case. This contradicts the letter of the Phelps' [106] theory from which Turnovsky derived the wage equations which form the basis for the estimates reported here as (3.47) through to (3.50). However, as was made clear in Chapter Two, a less strict model in which the coefficient of the expected rate of wage-inflation is a positive fraction (as in Model B.2) is well worthy of consideration. In fact, Turnovsky's work is interpreted here (but is not by him) as a test of this less strict model, namely the prototype Model E.2. On this interpretation, the results reported as (3.47), (3.48), (3.49) and (3.50) suggest that a non-degenerate long-run trade-off between unemployment and wage-inflation exists for Canada, this being the case because in all four of those estimations the coefficient of the expected rate of wage-inflation is significantly smaller than unity.<sup>34</sup>

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34. The values of the appropriate t statistic for (3.47), (3.48), (3.49) and (3.50) are respectively -4.756, -5.141, -3.209, -3.052 indicating rejection of the null hypothesis  $\delta = 1$  at the 5 per cent level of significance.

This conclusion is inconsistent with that drawn by Turnovsky from the earlier set of estimates based on the prototype Model A.2, although as was pointed out above that conclusion is open to some doubt.

## CHAPTER FOUR

### THE EMPIRICAL APPROACH

#### 4.1 Introduction

It will be recalled that two prototype models of the Expectations Hypothesis were discussed in Chapter Two - Model A and Model B. It will also be remembered that these models differ one from the other only with respect to the expectations variable which enters the wage equation. In Model A it is the expected percentage rate of change of prices, or the expected rate of inflation, which appears in the wage equation, while in Model B it is the expected percentage rate of change of money wage costs per man, or the expected wage-inflation rate, which appears. The common element of both models is a price equation linking the percentage rate of change of money wage costs with the actual inflation rate, and an equation describing the adjustment of the relevant expectations variable.

Two versions of Model A, designated Model A.1 and Model A.2, were considered in Chapter Two. The distinguishing feature of Model A.1 is that the expected rate of inflation enters the wage equation of the model with a coefficient of unity while in Model A.2 the expected rate of inflation enters the wage equation with a coefficient falling between zero and unity. Similarly, the two versions of Model B, designated Model B.1 and Model B.2, are distinguished by the fact that the expected wage-inflation rate enters the wage equation of Model B.1 with unit coefficient while

it enters that of Model B.2 with a coefficient falling between zero and unity.

One of the main aims of this thesis is to determine empirically whether any of the models A.1, A.2, B.1 and B.2 is appropriate for the Australian economy. The present chapter is concerned with the general approach adopted in the empirical work which was undertaken in pursuit of this aim. A discussion of the data used in this empirical work is given in Chapter Five while the results are presented and discussed in Chapter Six.

For purposes of empirical testing the four models in question were modified in two ways. The first modification was to drop the price equation from the models thereby reducing them to two-equation systems consisting of a wage equation and an expectations adjustment equation. This change in no way affects the validity of the testing procedure because the price equation is the same in all models and serves only to link the rate of inflation and the rate of wage-inflation. Furthermore, the inclusion of the price equation in empirical versions of the models increases the possibility of misspecification considerably while adding little that is useful. The second modification was to convert the models from the *continuous* formulation employed in Chapter Two to a *discrete* formulation. This change is, of course, forced on us by the fact that it is possible to observe economic variables only at discrete time intervals. With these modifications the four models are as follows.

*Model A*

$$w_t = f(u_t) + \delta p_t^e + \epsilon_t \quad (4.1)$$

$$p_t^e - p_{t-1}^e = \gamma(p_{t-1} - p_{t-1}^e) + \eta_t \quad (4.2)$$

In Model A.1,  $\delta = 1$  while in Model A.2,  $0 < \delta < 1$ .  $\epsilon_t$  and  $\eta_t$  denote random disturbances.

*Model B*

$$w_t = f(u_t) + \delta w_t^e + \epsilon_t \quad (4.3)$$

$$w_t^e - w_{t-1}^e = \gamma(w_{t-1} - w_{t-1}^e) + \eta_t \quad (4.4)$$

In Model B.1,  $\delta = 1$  while in Model B.2,  $0 < \delta < 1$ .

The plan of the remainder of this chapter is as follows. The various ways in which the unobservable expectations variables  $p^e$  and  $w^e$  can be dealt with are considered critically in Section 4.2. In Section 4.3 the specification of the expectations adjustment equation of the prototype models is examined in some detail. The final two sections, 4.4 and 4.5, are concerned respectively with the method of estimation used and the approach adopted for the treatment of autocorrelation.

## 4.2 The Expectations Variables

Three ways of dealing with the expectations variables  $p^e$  and  $w^e$  were observed in the overseas empirical work on the Expectations Hypothesis surveyed in Chapter Three. We have referred to these as the Proxied Expectations (PE) approach, the Observed Expectations (OE)

approach and the Reduced Form (RF) approach. The RF approach is the one adopted here. The reasons for this will be clear from the following discussion in which each of the three approaches in question is examined and assessed.

The PE approach was used by Solow [120] in his work on the United States and the United Kingdom, by Toyoda [129] in his work on the Japanese economy and by Vanderkamp [136] in his work on the Canadian economy. Briefly the method is as follows. The expectations adjustment mechanism is assumed to take some particular form. The adaptive scheme is commonly used but it is possible to operate with other schemes. For purposes of illustration, suppose the adaptive scheme

$$p_t^e - p_{t-1}^e = \gamma(p_{t-1} - p_{t-1}^e)$$

was adopted. A value would be selected for  $\gamma$  and using actually observed values for  $p$  a series for  $p^e$  conditional on the chosen value of  $\gamma$  is generated recursively. The process would then be repeated for as many values of  $\gamma$  as desired.<sup>1</sup> In the current context, the

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1. An important reason for adopting the conventional adaptive expectations scheme when using the Proxied Expectations Method is that it contains only a single parameter. If values of  $\gamma$  in steps of 0.1 are considered, 9 separate  $p^e$  series will result, corresponding to  $\gamma = 0.1, 0.2, \dots, 0.8, 0.9$ . However if a higher order scheme is adopted such as  $p_t^e - p_{t-1}^e = \gamma_1(p_{t-1} - p_{t-1}^e) + \gamma_2(p_{t-2} - p_{t-2}^e)$  the parameter space becomes two-dimensional and to the same degree of tolerance, 81 separate  $p^e$  series result, corresponding to  $(\gamma_1, \gamma_2) = (0.1, 0.1); (0.1, 0.2); \dots (0.9, 0.8); (0.9, 0.9)$ . The computational effort involved would therefore normally preclude the adoption of an expectations adjustment scheme which contained more than a single parameter.

wage equation in question would then be estimated using each of the conditional  $p^e$  series in turn. Finally, one of these estimated equations would be selected on the basis of conventional econometric criteria and the value of  $\gamma$  upon which the corresponding  $p^e$  series was conditional would be taken as the estimate of  $\gamma$ .

The deficiencies of the PE approach are considerable. In the first place, the estimates of all other parameters in the model under consideration (in our case the estimates of the parameters of the wage equation) are conditional on the chosen expectations adjustment scheme, on the value of  $\gamma$  from which the preferred  $p^e$  series is generated and on the initial value chosen for  $p^e$ . The last point arises because the  $p^e$  series are generated recursively and a starting value for  $p^e$  must be supplied to begin the recursive operation. To avoid this difficulty Solow [120, p. 8] commenced the generation of his  $p^e$  series some sixteen periods prior to the beginning of the sample period and set the first  $p^e$  equal to the corresponding  $p$ , his assumption being that any distortion introduced by the chosen initial  $p^e$  value would have worked itself out prior to the beginning of the sample period.<sup>2</sup>

Another important deficiency inherent in the PE approach is that no econometric assessment of the expectations scheme is possible because its parameter(s) are not subject to econometric

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2. Note, however, that the extent of the distortion introduced by the choice of starting value is, itself, dependent on the value of  $\gamma$ . When  $\gamma$  is close to unity, any starting value error will work itself out quite quickly. On the other hand, when  $\gamma$  is close to zero such errors will persist for a large number of periods. Accordingly, much less reliance can be placed on those  $p^e$  series which are conditional on small values of  $\gamma$  than on those for high values.

estimation. When the conditionality of the parameter estimates on the form of the expectations adjustment scheme and the impossibility of subjecting that scheme to any econometric assessment are considered together, it is apparent that the PE approach suffers from quite severe deficiencies. For these reasons, this approach was rejected.

Turn now to the OE approach. Although the expectations variables are not observable in the usual sense of being obtainable by traditional statistical collection, various ways have been devised to obtain observed expectations data. For instance, Turnovsky and Wachter [134] used an observed expectations series due to J. A. Livingston of the *Philadelphia Bulletin* which he obtained by asking "... a number of informed business economists their predictions for ... the Consumer Price Index ... and the average weekly wages in manufacturing." [134, p. 50] Conceptually, there are no difficulties inherent in the use of observed expectations data. The practical problems, however, are often considerable. As was discussed in Chapter Two,<sup>3</sup> the expectations required are those of the participants to the wage bargain. Unfortunately, available observed expectations data rarely reflect the required expectations. The work of Turnovsky and Wachter, for instance, is open to criticism on the grounds that the inflationary *predictions* of "informed business economists" may well bear very little resemblance to the inflationary *expectations* of wage bargain participants if only because these groups of individuals are forming their predictions or expectations on the basis of entirely different

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3. See p. 35.



types of information, the imperfections of which are likely also to differ considerably between the groups.

Three observed expectations series have to date been published for Australia. All three are due to efforts of officers of the Reserve Bank of Australia. Two were published by Jonson and Mahoney [61] in Vol. 49 (1973) of the *Economic Record* while the third, due to Danes [16], appeared in Vol. 14 (1975) of *Australian Economic Papers*. The origin of the first of Jonson and Mahoney's observed expectations series is similar to that of the Livingston series referred to above. It was obtained from Philip Shrapnel and Company, a market research organization. Shrapnel produces bi-annual forecasts of the "... annual change in the price level". [61, p. 52] Jonson and Mahoney obtained a series for quarterly predictions by linear interpolation of the original series. Apart from the questionable reliability of the Shrapnel series for the present purpose it suffers from the deficiency that it in no way represents the *expectations* of participants to the wage bargain. Jonson and Mahoney's second observed expectations series is based on statements about inflation which appeared in the *Australian Financial Review* (AFR). Four Reserve Bank economists were presented with a collection of clippings from AFR and asked to "... infer the inflationary expectations likely to be generated by [them] ..." [61, p. 52] The final AFR expectations series was an average of the four individual series. Here again, putting aside questions of reliability, it is not clear whose expectations (if any) the AFR series represents and it is certainly not possible to associate it with any of the parties to wage bargains.

The source data for Danes' observed inflationary expectations series is the *Australian Chamber of Manufacturers/Bank of New South Wales Survey of Industrial Trends*. The survey has been undertaken quarterly since 1966 and covers some 500 manufacturing firms which is said to be about 23 per cent of all manufacturing firms, measured by employment. The survey includes the following question. "Excluding normal seasonal changes, what has been your company's experience over the past three months and what changes do you expect during the next three months in respect of average selling prices?" [16, p. 78] The answers to each part of the question are classified into the categories "Up", "Down", "Same" and "No Answer". Danes used a technique developed by Carlson and Parkin [11, 12] to transform this qualitative information into a quantitative inflationary expectations series.<sup>4</sup> Although the Danes observed expectations series represents a significant improvement on the Shrapnel and AFR series, considerable problems remain. A major deficiency is that it does not reflect genuine inflationary expectations but expectations of average selling price increases of manufactured goods. Furthermore, the expectations are being formed by entrepreneurs who are in a position to set prices and hence are in a position to know what they intend to do with their own prices in the near future. In this sense, the expectations are being formed on the basis of much better information than is the case with an ordinary inflationary expectation, for instance, one formed by workers about the goods and services they purchase. Another, perhaps lesser, deficiency of the Danes series is that it can be associated,

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4. Other very similar methods have been described by Knöbl [66] and by de Menil and Bhalla [17].

at best, with only one of the participants to the wage bargain, namely the employers. The inflationary expectations of workers are at least as important and must be taken into account.

The Carlson-Parkin technique is a useful one in the sense that if applied to the right type of survey data a legitimate observed expectations series can be obtained. Unfortunately, appropriate source data is not currently available for Australia.<sup>5</sup> The use of observed inflationary expectations data had therefore to be rejected because the existing series did not reflect the required groups' expectations, and it was not possible to construct a new series in the absence of appropriate source survey data.

The final method of treating the "unobservable" expectations variables and the one adopted for the purposes of this study is the RF approach. Consider Model A.2 for purposes of illustration.

Putting<sup>6</sup>  $f(u_t) = a_0 + a_1 u_t^{-1}$  the structural form of Model A.2 is

5. The Roy Morgan Research Centre Pty. Ltd. conducts a quarterly survey of consumer confidence called "Pulse". It includes questions concerning respondents' expectations regarding price and wage changes which could be used to produce inflationary expectations and wage-inflation expectations series via the Carlson-Parkin technique. Unfortunately, the survey has been conducted only since July, 1973 so that too few observations are presently available to make it worth pursuing for the time being. A further difficulty is that negotiations with the company to obtain their quarterly report broke down when they insisted on an annual subscription fee of \$2400.
6. This is a common form used for  $f(u_t)$ . Its derivatives are  $f'(u_t) = -a_1 u_t^{-2}$  and  $f''(u_t) = +2a_1 u_t^{-3}$  which satisfy the sign restrictions  $f' < 0$ ,  $f'' > 0$  when  $a_1$  is positive and the intercept restriction  $f(u) = 0$  for some  $u > 0$  when  $a_0$  is negative, the  $u$  intercept in question being  $-a_1/a_0$ .

$$w_t = a_0 + a_1 u_t^{-1} + \delta p_t^e \quad (4.5)$$

$$p_t^e - p_{t-1}^e = \gamma(p_{t-1} - p_{t-1}^e) \quad (4.6)$$

The variables  $w_t$  and  $p_t^e$  are endogenous while the remainder are predetermined,  $u_t$  and  $p_{t-1}$  being exogenous while  $p_{t-1}^e$  is lagged endogenous. The reduced form of this system<sup>7</sup> is

$$w_t = a_0 \gamma + a_1 u_t^{-1} - a_1 (1 - \gamma) u_{t-1}^{-1} + \delta \gamma p_{t-1} + (1 - \gamma) w_{t-1} \quad (4.7)$$

$$p_t^e = \gamma p_{t-1} + (1 - \gamma) p_{t-1}^e \quad (4.8)$$

The important feature of the reduced form is that the equation for  $w_t$ , namely (4.7), does not contain any unobservable variable.<sup>8</sup>

Furthermore all the structural parameters appear in the reduced form equation for  $w_t$  although that equation is non-linear in the *structural* parameters. Accordingly estimates of all the structural parameters of the model can be obtained from an appropriate estimation<sup>9</sup> of the reduced form equation for  $w_t$  without encountering the problem which arises from the appearance of unobservable expectations variables.

As was the case with the PE approach, the parameter estimates from the RF approach are conditional on the choice of the expectations

7. The derivation of the reduced form is as follows. (4.6) can be rearranged into  $p_t^e = \gamma p_{t-1} + (1 - \gamma) p_{t-1}^e$  which is (4.8) and shows that the structural equation (4.6) is "in reduced form" because  $p_{t-1}$  and  $p_{t-1}^e$  are both predetermined variables. Substituting (4.8) into (4.5) produces  $w_t = a_0 + a_1 u_t^{-1} + \gamma \delta p_{t-1} + (1 - \gamma) \delta p_{t-1}^e$ . From (4.5),  $\delta p_t^e = w_t - a_0 - a_1 u_t^{-1}$  hence  $(1 - \gamma) \delta p_{t-1}^e = (1 - \gamma) w_{t-1} - a_0 (1 - \gamma) - a_1 (1 - \gamma) u_{t-1}^{-1}$ . Substituting this expression into the previous one for  $w_t$  and rearranging produces (4.7).

8. It could not, of course, contain  $p_t^e$  by definition, but  $p_{t-1}^e$  might have appeared.

9. See below, p. 115.

adjustment scheme. Unlike the PE approach however, estimates of the parameters of the expectations adjustment equation are forthcoming from the estimation of the reduced form which allows that equation to be subjected to econometric assessment. The last point notwithstanding, the selection of the form of the expectations adjustment scheme is quite critical. Saunders and Nobay [118] found in a study concerned with assessing the effectiveness of post-war incomes policy in the United Kingdom, which was based on a wage equation of the same form as (4.1), that "... an alternative expectations scheme yields the same reduced form<sup>10</sup> as an adaptive expectations model but implies a structural parameter<sup>11</sup> for [inflationary] expectations which is substantially higher and nearer in the region of unity". [118, p. 248] This provides empirical support for the assertion made by Sargent [116] that imposing an expectations adjustment scheme in which the distributed lag weights on  $p_t$ ,  $p_{t-1}$ ,  $p_{t-2}$ , ... inappropriately sum to unity, as may be true in the case of the adaptive expectations scheme, produces a downward bias on the coefficient of inflationary expectations in the wage equation.

While the RF approach is not without deficiencies it is certainly preferable to the PE approach. The OE approach represents a useful alternative but for the time being has to be rejected for Australia because the required survey data are not available.

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10. The relationships between the reduced form and structural coefficients will be different, however.

11. The parameter referred to corresponds to  $\delta$  in (4.1).

#### 4.2 The Expectations Adjustment Equation

In formulating Models A and B, the adaptive expectations scheme<sup>12</sup> has been adopted for the expectations adjustment equation. As was pointed out earlier, the adaptive scheme has been used mainly for convenience and it is not necessarily the most appropriate form for the expectations adjustment equation. Another form which has frequently been used in the literature (e.g. by Turnovsky [130]) is the first-order *extrapolative* scheme:<sup>13</sup>

$$p_t^e = p_{t-1} + \alpha(p_{t-1} - p_{t-2}) \quad (4.9)$$

When  $\alpha$  is positive, past trends in the rate of inflation are expected to continue and the embodied expectations are said to be extrapolative. On the other hand, if  $\alpha$  is negative, a reversal of past trends is expected and the embodied expectations are described as regressive. A further form is the case of so-called *static* expectations:

$$p_t^e = p_{t-1} \quad (4.10)$$

which is the special case of the extrapolative scheme when  $\alpha = 0$ .

In this case, the actual inflation rate of the last period is expected to be maintained in the current period.

12. The adaptive expectations scheme in question  $p_t^e - p_{t-1}^e = \gamma(p_{t-1} - p_{t-1}^e)$  is more correctly described as the first-order adaptive scheme because higher-order adaptive schemes can also be defined. For instance, the second-order adaptive scheme is  $p_t^e - p_{t-1}^e = \gamma_1(p_{t-1} - p_{t-1}^e) + \gamma_2(p_{t-2} - p_{t-2}^e)$ .
13. As was the case with the adaptive scheme, higher-order extrapolative schemes can also be defined. For instance, the second-order extrapolative scheme is  $p_t^e = p_{t-1} + \alpha_1(p_{t-1} - p_{t-2}) + \alpha_2(p_{t-2} - p_{t-3})$ .

It is desirable that the choice between the extrapolative and adaptive schemes be made on empirical grounds as it is only in this way that the problems referred to by Saunders and Nobay [118]<sup>14</sup> arising from the effect on the estimate of  $\delta$  of the selection of a particular expectations adjustment scheme can be avoided. The choice might be made by separately estimating the reduced form equation for each scheme and comparing the results. However, such a comparison would be invalidated by the fact that each set of parameter estimates would be conditional on the choice of expectations adjustment scheme.<sup>15</sup>

A preferable approach is to employ an expectations adjustment scheme which embraces *both* the adaptive and extrapolative schemes. Such a scheme is<sup>16</sup>

$$p_t^e = (\alpha + \gamma)p_{t-1} - \alpha p_{t-2} + (1 - \gamma)p_{t-1}^e \quad (4.11)$$

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14. See above, p. 108.

15. See above, p. 107.

16. Valentine [135] makes use of a scheme which he attributes to Rose [112] and which is claimed to contain both the adaptive and extrapolative schemes. The scheme in question is

$$p_t^e = p_t + \theta_1(p_t - p_{t-1}) + \theta_2(p_t - p_{t-1}^e)$$

which is said to give extrapolative expectations with  $\theta_2 = 0$  and adaptive expectations when  $\theta_1 = 0$ . Neither claim is correct, however, if the schemes in question are defined in the usual way. Furthermore, it is not possible to make any straightforward modifications to bring the Valentine-Rose scheme into line with the usual definitions of the adaptive and extrapolative schemes jointly.

With  $\alpha = 0$ , (4.11) reduces to

$$p_t^e = \gamma p_{t-1} + (1 - \gamma)p_{t-1}^e$$

which rearranges into the adaptive expectations scheme as previously defined:

$$p_t^e - p_{t-1}^e = \gamma(p_{t-1} - p_{t-1}^e)$$

With  $\gamma = 1$ , (4.11) reduces to

$$p_t^e = (\alpha + 1)p_{t-1} - \alpha p_{t-2}$$

which can be rearranged to give

$$p_t^e = p_{t-1} + \alpha(p_{t-1} - p_{t-2}),$$

the extrapolative scheme as previously defined. With  $\alpha = 0$  and  $\gamma = 1$ , the static expectations scheme previously referred to is obtained from (4.11).

The mixed expectations scheme (4.11) also contains the process noted by Valentine [135, p. 3] in which the change in the inflationary expectation is proportional to the most recent change<sup>17</sup> in the actual inflation rate. With  $\gamma = 0$ , (4.11) reduces to

$$p_t^e = \alpha p_{t-1} - \alpha p_{t-2} + p_{t-1}^e$$

which is equivalent to

$$p_t^e - p_{t-1}^e = \alpha(p_{t-1} - p_{t-2}), \quad (4.12)$$

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17. Valentine actually referred to the contemporaneous change in each of the variables.



which is the process just referred to,  $\alpha$  being the constant of proportionality in question.

Two modifications have already been made to Models A.1, A.2, B.1 and B.2 for purposes of empirical testing. They will now be further modified, the adaptive expectations scheme being replaced by the more general mixed expectations scheme (4.11). The current versions of the four prototype models are therefore as follows.

#### *Model A*

$$w_t = f(u_t) + \delta p_t^e + \epsilon_t \quad (4.13)$$

$$p_t^e = (\alpha + \gamma)p_{t-1} - \alpha p_{t-2} + (1 - \gamma)p_{t-1}^e + \eta_t \quad (4.14)$$

#### *Model B*

$$w_t = f(u_t) + \delta w_t^e + \epsilon_t \quad (4.15)$$

$$w_t^e = (\alpha + \gamma)w_{t-1} - \alpha w_{t-2} + (1 - \gamma)w_{t-1}^e + \eta_t \quad (4.16)$$

As before, Models A.1 and B.1 are respectively Models A and B with  $\delta = 1$  while Models A.2 and B.2 are Models A and B respectively with  $0 < \delta < 1$ .  $\epsilon_t$  and  $\eta_t$  again denote random disturbances.

### 4.3 The Method of Estimation

When  $a_0 + a_1 u_t^{-1}$  is substituted<sup>18</sup> for  $f(u_t)$  in (4.13), the structural form of Model A is

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18. See above, p. 106.

$$w_t = a_0 + a_1 u_t^{-1} + \delta p_t^e + \epsilon_t \quad (4.17)$$

$$p_t^e = (\alpha + \gamma)p_{t-1} - \alpha p_{t-2} + (1 - \gamma)p_{t-1}^e + \eta_t \quad (4.18)$$

The equation for  $w_t$  in the reduced form of this two equation system can be obtained as follows. Substituting (4.18) into (4.17) produces

$$w_t = a_0 + a_1 u_t^{-1} + (\alpha + \gamma)\delta p_{t-1} - \alpha\delta p_{t-2} + (1 - \gamma)\delta p_{t-1}^e + \epsilon_t + \delta\eta_t \quad (4.19)$$

From (4.17),

$$\delta p_t^e = w_t - a_0 - a_1 u_t^{-1} - \epsilon_t$$

Therefore,

$$(1 - \gamma)\delta p_{t-1}^e = (1 - \gamma)w_{t-1} - a_0(1 - \gamma) - a_1(1 - \gamma)u_{t-1}^{-1} - (1 - \gamma)\epsilon_{t-1} \quad (4.20)$$

Substituting (4.20) into (4.19) and rearranging yields the required equation for  $w_t$  in the reduced form of Model A:

$$w_t = a_0\gamma + a_1 u_t^{-1} - a_1(1 - \gamma)u_{t-1}^{-1} + (\alpha + \gamma)\delta p_{t-1} - \alpha\delta p_{t-2} + (1 - \gamma)w_{t-1} + V_t \quad (4.21)$$

where  $V_t = \epsilon_t - (1 - \gamma)\epsilon_{t-1} + \delta\eta_t$ .

The structural form of Model B after replacing  $f(u_t)$  in (4.15) by  $a_0 + a_1 u_t^{-1}$  is

$$w_t = a_0 + a_1 u_t^{-1} + \delta w_t^e + \varepsilon_t \quad (4.22)$$

$$w_t^e = (\alpha + \gamma)w_{t-1} - \alpha w_{t-2} + (1 - \gamma)w_{t-1}^e + \eta_t \quad (4.23)$$

The derivation of the Model B reduced form equation for  $w_t$  follows precisely similar lines to that described above for Model A. The resulting Model B equation is:

$$\begin{aligned} w_t = & a_0 \gamma + a_1 u_t^{-1} - a_1 (1 - \gamma) u_{t-1}^{-1} + [1 - \gamma + (\alpha + \gamma) \delta] w_{t-1} \\ & - \alpha \delta w_{t-2} + V_t \end{aligned} \quad (4.24)$$

where  $V_t = \varepsilon_t - (1 - \gamma)\varepsilon_{t-1} + \delta\eta_t$ .

Of course,  $f(u_t) = a_0 + a_1 u_t^{-1}$  is only one of the possible forms that could be adopted for  $f(u_t)$ . Expressions similar to (4.21) and (4.24) corresponding to other forms of  $f(u_t)$  can be obtained in the same way as described above. These expressions will differ from (4.21) and (4.24) only as regards the first three terms in each of those cases and, in particular, the coefficients of  $p_{t-1}$ ,  $p_{t-2}$ ,  $w_{t-1}$  and  $w_{t-2}$  and the form of the expression for  $V_t$  will not be any different.

As was noted earlier, the important feature of the reduced form equations (4.21) and (4.24) is that no unobservable expectations variables appear. From the point of view of estimation, the features of these reduced form equations are their non-linearity in the *structural* parameters and the over-identification of those structural parameters. The non-linearity arises, for example, because the coefficient of  $p_{t-2}$  in (4.21) is the product of the structural parameters  $\alpha$  and  $\delta$ . To demonstrate the over-identification of the structural parameters in the reduced form equation for  $w_t$  of Model A, (4.21) is rewritten as

$$w_t = \beta_0 + \beta_1 u_t^{-1} + \beta_2 u_{t-1}^{-1} + \beta_3 p_{t-1} + \beta_4 p_{t-2} + \beta_5 w_{t-1} + v_t \quad (4.25)$$

where  $\beta_0, \beta_1, \dots, \beta_5$  are reduced form coefficients and are related to the structural parameters according to

$$\begin{aligned} \beta_0 &= u_0 \gamma & \beta_3 &= (\alpha + \gamma) \delta \\ \beta_1 &= a_1 & \beta_4 &= -\alpha \delta \\ \beta_2 &= -a_1(1 - \gamma) & \beta_5 &= (1 - \gamma) \end{aligned} \quad (4.26)$$

There are five structural parameters ( $a_0, a_1, \alpha, \gamma$  and  $\delta$ ) and six reduced form coefficients ( $\beta_0, \beta_1, \dots, \beta_5$ ) so the relationships (4.26) comprise a system of six equations in only five unknowns. It is therefore impossible to obtain unique solutions for the structural parameters given the reduced form coefficients, indicating that the structural parameters are over-identified. The over-identification of the structural parameters of Model B can be shown in a similar fashion. Since estimates of the structural parameters are required, estimates of the reduced form coefficients being of no interest, a non-linear estimation technique is called for, in which all the identifying restrictions on the structural parameters can be imposed.

Various non-linear estimation techniques are available.

In the present study the Non-Linear Least Squares (NLLS) algorithm developed by Marquardt [78] was employed. Marquardt's algorithm is a modified Gauss-Newton<sup>19</sup> method which has been found to be of

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19. For a general description of non-linear least squares methods see Draper and Smith [22], pp. 263-304. See also Malinvaud [76], pp. 341-348.

considerable practical usefulness in estimation situations similar to the one presently under discussion.<sup>20</sup> Although the properties of the NLLS estimator have not been developed in very great depth, Malinvaud [76, pp. 329-331], Hartley and Booker [44] and Jennrich [56] have all shown it to be consistent under assumptions which resemble those of the Classical Regression Model. If the non-linear regression model is

$$Y_t = f(x_t, \theta) + V_t \quad t = 1, 2, \dots, T$$

where  $Y_1, Y_2, \dots, Y_T$  is a set of  $T$  responses,  $x_t$  is the  $t^{\text{th}}$  input vector of  $k$  elements which gives rise to  $Y_t$ ,  $\theta$  is an  $m$ -element vector of unknown parameters,  $f$  is a known continuous function, and  $V_1, V_2, \dots, V_T$  are random disturbances, then the assumptions<sup>21</sup> referred to under which the NLLS estimator is consistent are that (i) the elements of the vector  $x_t$  are fixed and (ii) the  $V_t$  are a set of independent random variables which are normally distributed with zero mean and common (unknown) variance  $\sigma^2$ . In addition, the non-linear function  $f$  is assumed to satisfy certain regularity conditions. The approximate asymptotic variance-covariance matrix for the NLLS estimators  $\hat{\theta} = (\hat{\theta}_1, \hat{\theta}_2, \dots, \hat{\theta}_m)$  is given by Hartley and Booker [44, p. 641] as

$$\text{Cov}(\hat{\theta}_i, \hat{\theta}_j) = \hat{\sigma}^2 \left( \sum_{t=1}^T f_i(x_t, \theta) f_j(x_t, \theta) \right)^{-1}$$

where  $f_i$  denotes  $\partial f(x_t, \theta) / \partial \theta_i$  and  $\hat{\sigma}^2$  is the sum of the squared

20. See Draper and Smith [22, p. 272] and Box and Jenkins [7, p. 504]. Convergence problems are frequently encountered with non-linear estimation techniques which are of an iterative nature. A particular advantage of the Marquardt procedure is that such difficulties very rarely arise.

21. As was foreshadowed earlier, the assumptions in question correspond very closely to those of the Classical Regression Model, the major difference being the substitution of a general form for the regression equation.

residuals evaluated at  $\hat{\theta}$  divided by  $(T - k)$ . Jennrich [56, pp. 639-640] and Malinvaud [76, pp. 331-338] establish that the random variable<sup>22</sup>  $(\hat{\theta}_1 - \theta_1)/\hat{\sigma}_{\hat{\theta}_1}$ , upon which the ordinary t-test is based, is asymptotically normal with variance unity, given the same set of assumptions outlined above. By virtue of the consistency of the NLLS estimator  $\hat{\theta}_1$ , it must also be asymptotically unbiased. The implication of these results is that the usual tests of hypotheses are valid asymptotically.

#### 4.4 Treatment of Autocorrelation

As pointed out above, one of the requirements for consistency of the NLLS estimator is that the disturbances be independent, a necessary condition for which is that the disturbances be not autocorrelated. Unfortunately, the presence of autocorrelation in the reduced form disturbance can be expected in the present situation. For instance, consider the following structural form of Model A:

$$w_t = a_0 + a_1 u_t^{-1} + \delta p_t^e + \varepsilon_t \quad (4.27)$$

$$p_t^e = (\alpha + \gamma)p_{t-1} - \alpha p_{t-2} + (1 - \gamma)p_{t-1}^e + \eta_t \quad (4.28)$$

Suppose that the following standard stochastic specification is imposed. (i) Each of the disturbances  $\varepsilon_t$  and  $\eta_t$  has zero expectation, (ii) each has a constant finite variance denoted by  $\sigma_\varepsilon^2$  and  $\sigma_\eta^2$  respectively, (iii) neither is autocorrelated and (iv) they are contemporaneously uncorrelated. The equation for  $w_t$  in the reduced

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22. As usual,  $\hat{\sigma}_{\hat{\theta}_1}$  denotes the positive square root of  $\text{cov}(\hat{\theta}_1, \hat{\theta}_1)$  as defined earlier.

form of the system (4.27) and (4.28) is

$$w_t = a_0\gamma + a_1u_t^{-1} - a_1(1 - \gamma)u_{t-1}^{-1} + (\alpha + \gamma)\delta p_{t-1} - \alpha\delta p_{t-2} \\ + (1 - \gamma)w_{t-1} + v_t \quad (4.29)$$

$$\text{where } v_t = \varepsilon_t - (1 - \gamma)\varepsilon_{t-1} + \delta\eta_t \quad (4.30)$$

Using (4.30),

$$v_t v_{t-1} = [\varepsilon_t - (1 - \gamma)\varepsilon_{t-1} + \delta\eta_t][\varepsilon_{t-1} - (1 - \gamma)\varepsilon_{t-2} + \delta\eta_{t-1}] \\ = \varepsilon_t \varepsilon_{t-1} - (1 - \gamma)\varepsilon_t \varepsilon_{t-2} + \delta\varepsilon_t \eta_{t-1} - (1 - \gamma)\varepsilon_{t-1}^2 \\ + (1 - \gamma)^2 \varepsilon_{t-1} \varepsilon_{t-2} - (1 - \gamma)\delta\varepsilon_{t-1} \eta_{t-1} \\ + \delta\varepsilon_{t-1} \eta_t - (1 - \gamma)\delta\varepsilon_{t-2} \eta_t + \delta^2 \eta_t \eta_{t-1} \quad (4.31)$$

In view of the assumption that each of  $\varepsilon_t$  and  $\eta_t$  has zero expectation, the same is true of  $v_t$  from (4.30). This being the case the covariance between  $v_t$  and  $v_{t-1}$  is  $E(v_t v_{t-1})$ . From (4.31),

$$\text{cov}(v_t, v_{t-1}) = E(v_t v_{t-1}) \\ = -(1 - \gamma)E(\varepsilon_{t-1}^2),$$

using the assumptions of absence of autocorrelation and mutual uncorrelatedness of  $\varepsilon_t$  and  $\eta_t$ . Finally, using the assumptions that  $\varepsilon_t$  has zero expectation and variance  $\sigma_\varepsilon^2$ ,

$$\text{cov}(v_t, v_{t-1}) = -(1 - \gamma)\sigma_\varepsilon^2 \quad (4.32)$$

Thus, when inflationary expectations are adaptive or conform with the mixed scheme (4.11),<sup>23</sup> i.e. when  $\gamma \neq 1$ , the reduced form disturbance  $V_t$  will be subject to first-order autocorrelation. If, as is usually expected,  $0 < \gamma < 1$  then  $V_t$  is subject to *negative* first-order autocorrelation. On the other hand, if expectations are extrapolative, i.e. if  $\gamma = 1$ , autocorrelation is absent from  $V_t$ . The conclusion that  $V_t$  exhibits first-order autocorrelation is, of course, conditional on the assumptions made about the structural disturbances  $\epsilon_t$  and  $\eta_t$ . It can be shown that higher-order autocorrelation will be present in  $V_t$  if either of  $\epsilon_t$  or  $\eta_t$  is autocorrelated or if, in addition to at least one of  $\epsilon_t$  and  $\eta_t$  being autocorrelated, they are contemporaneously correlated with each other.

Because autocorrelation was likely to be present and because it was desirable from the point of view of consistency of estimation that it should not be present, considerable effort was spent in devising a systematic procedure for detecting autocorrelation and for removing it once detected. The development of a satisfactory detection procedure posed the more difficult problem in the current context because the results on which the familiar tests for the presence of autocorrelation are based are derived on the assumption that the regression equation in question is linear in the parameters. This remark applies to both the Durbin-Watson [25] test and the Durbin [24] test. The Durbin-Watson test would not be applicable in any event because the equation to be estimated here always includes a lagged value of the dependent variable. Some researchers faced with this problem have ignored the non-linearity of the equation

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23. See above, p. 110.



being estimated and have employed the (otherwise) appropriate Durbin-Watson or Durbin test in the usual way.<sup>24</sup> A preferable approach and the one which was adopted here is the procedure implicit in Pagan [88]. The equation under study is estimated in the required manner<sup>25</sup> and the correlogram<sup>26</sup> of its residuals calculated. The residual correlogram is examined and autocorrelation is deemed to be present if any of its ordinates are significantly different from zero at the 5 per cent level.

The procedure adopted for the treatment of autocorrelation once detected is a modification of the procedure suggested by Eckstein and Wyss [27].<sup>27</sup> For illustrative purposes suppose that

24. This approach was adopted, for example, by Parkin [91]. See, for instance, his constrained estimations on pp. 137-8.

25. It should be emphasized that this approach to the detection of autocorrelation is in no way dependent on the NLLS method of estimation. It is equally applicable when the equation under study is being estimated by any other method, by OLS for instance.

26. The estimator of the  $k^{\text{th}}$  autocorrelation  $\psi_k$  used was

$$\hat{\psi}_k = \frac{C_k}{C_0}$$

$$\text{where } C_k = (T - k)^{-1} \sum_{t=1}^{T-k} (z_t - \bar{z})(z_{t+k} - \bar{z}) \quad k = 0, 1, 2, \dots, K$$

and where  $z_1, z_2, \dots, z_T$  is the series in question and  $\bar{z}$  denotes its sample mean.  $K$  was set at an integer not larger than  $T/4$ . See Box and Jenkins [7, p. 33]. The residual correlogram ordinates are approximately Normally distributed with mean zero and asymptotic variance  $T^{-1}$  [7, p. 290] except when the equation in question includes lagged values of the dependent variable in which case  $T^{-1}$  understates the variance at low lags but is otherwise an adequate approximation. See Durbin [24] and Box and Pierce [8]. The properties of the above estimator of the  $k^{\text{th}}$  autocorrelation are discussed in Jenkins and Watts [55], pp. 174-189.

27. A similar procedure was suggested by Fuller and Martin [31].

the equation to be estimated takes the form:

$$Y_t = \beta_0 + \beta_1 X_t + V_t \quad (4.33)$$

The Eckstein-Wyss procedure postulates that the disturbance  $V_t$  is subject to autocorrelation according to an autoregressive scheme. Again for purposes of illustration suppose that  $V_t$  conforms to a first-order autoregressive scheme:

$$V_t = \rho V_{t-1} + \epsilon_t \quad (4.34)$$

where  $\epsilon_t$  has the Classical disturbance properties. A Cochrane-Orcutt<sup>28</sup> transformation is then applied, reducing (4.33) and (4.34) to

$$Y_t = \beta_0(1 - \rho) + \beta_1 X_t - \beta_1 \rho X_{t-1} + \rho Y_{t-1} + \epsilon_t \quad (4.35)$$

The important feature of (4.35) is that its disturbance is  $\epsilon_t$  which is not autocorrelated. Equation (4.35) is estimated using NLLS. From this estimation, parameter estimates of  $\beta_0$  and  $\beta_1$  and their standard errors *corrected for the postulated autocorrelation* are produced.

In addition an estimate of  $\rho$  and its standard error is available from the NLLS estimation of (4.35). The estimate of  $\rho$  is then examined. If  $\rho$  is found to be insignificantly different from zero at the 5 per cent level this is taken to be an indication that the chosen autocorrelation scheme is misspecified and the entire procedure is repeated after reconsidering the specification of the autocorrelation scheme. On the other hand, if  $\rho$  turns out to be significantly different from zero at the 5 per cent level and there are no ordinates

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28. See Cochrane and Orcutt [14].

present in the residuals correlogram of the corrected equation (4.35) which are significantly different from zero at the 5 per cent level then the estimates of  $\beta_0$  and  $\beta_1$  obtained from the NLLS estimation of (4.35) are retained.

The only potential stumbling block in the application of the procedure for treating autocorrelation just outlined is the selection of the form of the autocorrelation scheme. For the Cochrane-Orcutt transformation (which is central to the method) to be viable, the autocorrelation scheme must take an autoregressive form. Examples are

$$V_t = \rho V_{t-1} + \epsilon_t \quad (4.36)$$

$$V_t = \rho_1 V_{t-1} + \rho_2 V_{t-2} + \epsilon_t \quad (4.37)$$

$$V_t = \rho_4 V_{t-4} + \epsilon_t \quad (4.38)$$

In particular, a moving-average scheme such as

$$V_t = \epsilon_t + \theta \epsilon_{t-1} \quad (4.39)$$

is excluded because no transformation is available which will produce an equation like (4.35) whose disturbance is not autocorrelated.

This is unfortunate in view of the earlier finding<sup>29</sup> that the disturbance of the reduced form equation (4.29) may be autocorrelated according to a scheme which is essentially a first-order moving-average in  $\epsilon_t$ .<sup>30</sup> It is generally accepted however that such a moving average

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29. See above, p. 118.

30. Compare (4.39) with (4.30).

scheme can be reasonably approximated by an autoregressive scheme.<sup>31</sup>  
 In any event Hendry and Trivedi [45] concluded from a simulation study that "... taking some account of autocorrelation, even if the form is mis-specified, is a superior policy to ignoring it completely." [45, p. 127]

The residual correlogram can be used to gain some insight into the appropriate order of the autoregressive scheme to be used in a particular estimation situation. Once the estimation has been performed the success of the autocorrelation correction can be gauged by checking the residuals correlogram of the corrected equation for absence of ordinates which are significantly different from zero at the 5 per cent level. Such a check also reflects on the appropriateness of the autoregressive scheme adopted. As mentioned above, a further check is that the parameters of the autoregressive scheme should be significant at the 5 per cent level.

The three autoregressive schemes mentioned above (4.36), (4.37) and (4.38) are the schemes most commonly found in the literature. In each case, it is necessary to impose restrictions on their parameters to guarantee the covariance stationarity of the random variable  $V_t$ . In the absence of the covariance stationarity requirement,  $V_t$  would exhibit behaviour which is quite implausible in economic contexts. For instance, both  $V_t$  and its variance could increase without limit. Box and Jenkins [7, pp. 53-54] have shown that the covariance stationarity restrictions in the case of the autoregressive process of order  $p$ :

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31. See Henry [46].

$$V_t = \phi_1 V_{t-1} + \phi_2 V_{t-2} + \dots + \phi_p V_{t-p} + \epsilon_t$$

are that the roots of

$$x^p - \phi_1 x^{p-1} - \dots - \phi_{p-1} x - \phi_p = 0$$

are all less than unity in absolute value. This result can be applied directly to the schemes of interest (4.36), (4.37) and (4.38).

In the case of the first-order scheme (4.36):

$$V_t = \rho V_{t-1} + \epsilon_t,$$

$V_t$  is covariance stationary if the root of  $x - \rho = 0$  is less than unity in absolute value. The root in question is, of course,  $\rho$ . In practice  $\rho$  is unknown but its NLLS estimate and the associated standard error will be available from the autocorrelation correction procedure outlined above.<sup>32</sup> It is therefore possible to test the null hypothesis  $\rho = 1$  against the alternative  $\rho < +1$  and the null hypothesis  $\rho = -1$  against the alternative  $\rho > -1$ , acceptance of *both* alternative hypotheses being equivalent to acceptance of the hypothesis that  $V_t$  is covariance stationary. An alternative approach is to establish that the (say) 99 per cent confidence limits for  $\rho$  lie entirely between plus and minus unity.

The derivation of the covariance stationarity restrictions in the case of the simple fourth-order autoregressive scheme<sup>33</sup> (4.37):

32. See pp. 120-121 above.

33. (4.37) is described as the simple fourth-order autoregressive scheme to distinguish it from the more general fourth-order scheme  $V_t = \rho_1 V_{t-1} + \rho_2 V_{t-2} + \rho_3 V_{t-3} + \rho_4 V_{t-4} + \epsilon_t$ .

$$V_t = \rho_4 V_{t-4} + \epsilon_t,$$

is also relatively straightforward. The restrictions are that the roots of  $x^4 - \rho_4 = 0$  are all less than unity in absolute value. It can be shown<sup>34</sup> that all four roots of  $x^4 - \rho_4 = 0$  have the same absolute value, namely  $\sqrt[4]{\rho_4}$ . Therefore, in the case of the simple fourth-order autoregressive scheme the covariance stationarity requirement is that  $\sqrt[4]{\rho_4}$  be less than unity. A completely equivalent requirement is that  $\rho_4$  be less than unity in absolute value. As was noted above with regard to the first-order scheme, the parameter  $\rho_4$  is unknown but the hypothesis that the covariance stationarity requirement is satisfied can be tested using the NLLS estimate of  $\rho_4$  and its standard error, the test procedure being identical to that described in the first-order case.

In the case of the second-order autoregressive scheme (4.37):

$$V_t = \rho_1 V_{t-1} + \rho_2 V_{t-2} + \epsilon_t$$

the covariance stationarity requirement is that the roots of  $x^2 - \rho_1 x - \rho_2 = 0$  are both less than unity in absolute value. Using a result established by Goldberg [33],<sup>35</sup> necessary and sufficient conditions for the roots of  $x^2 - \rho_1 x - \rho_2 = 0$  to be less than unity in absolute value are

$$\rho_2 + \rho_1 < 1 \quad \rho_2 - \rho_1 < 1 \quad \rho_2 > -1 \quad (4.40)$$

34. See Thomas [127], p. 849. The roots are given by

$\sqrt[4]{\rho_4} [\cos(\frac{\theta}{4} + k \frac{\pi}{2}) + i \sin(\frac{\theta}{4} + k \frac{\pi}{2})]$ ,  $k = 0, \pm 1, \pm 2$  where  $\theta$  satisfies  $\cos \theta = \rho_4 / |\rho_4|$  and  $\sin \theta = 0$ .

35. Theorem 4.2, p. 172.

In practice  $\rho_1$  and  $\rho_2$  are not known but the NLLS estimate of each, together with its standard error will be available. It is therefore necessary to test (i) the null hypothesis  $\rho_2 + \rho_1 = 1$  against the alternative hypothesis  $\rho_2 + \rho_1 < 1$ , (ii) the null hypothesis  $\rho_2 - \rho_1 = 1$  against the alternative  $\rho_2 - \rho_1 < 1$  and (iii) the null hypothesis  $\rho_2 = -1$  against the alternative  $\rho_2 > -1$ . All three null hypotheses need to be rejected at the appropriate level of significance to accept the hypothesis that  $V_t$  is covariance stationary. To perform the tests outlined above, estimates of  $\rho_2 + \rho_1$  and  $\rho_2 - \rho_1$  together with their standard errors are required. Denoting the estimates of  $\rho_1$  and  $\rho_2$  by  $\hat{\rho}_1$  and  $\hat{\rho}_2$ , their standard errors by  $\hat{\sigma}_{\hat{\rho}_1}$  and  $\hat{\sigma}_{\hat{\rho}_2}$  and their estimated covariance by  $\text{cov}(\hat{\rho}_1, \hat{\rho}_2)$ , the required estimates can be obtained using

$$\text{estimate of } (\rho_2 + \rho_1) = \hat{\rho}_2 + \hat{\rho}_1, \text{ and}$$

$$\text{estimate of } (\rho_2 - \rho_1) = \hat{\rho}_2 - \hat{\rho}_1,$$

and their common standard error is given by the positive square root of<sup>36</sup>

$$\hat{\sigma}_{\hat{\rho}_1}^2 + \hat{\sigma}_{\hat{\rho}_2}^2 + 2 \text{ cov}(\hat{\rho}_1, \hat{\rho}_2).$$

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36. An interesting alternative approach to the testing of the hypothesis of covariance stationarity in the second-order case is to obtain estimates of the roots of  $x^2 - \rho_1 x - \rho_2 = 0$ , say  $\hat{r}_1$  and  $\hat{r}_2$ , from  $\hat{r}_1 = \frac{1}{2}(\hat{\rho}_1 + \sqrt{\hat{\rho}_1^2 + 4\hat{\rho}_2})$  and  $\hat{r}_2 = \frac{1}{2}(\hat{\rho}_1 - \sqrt{\hat{\rho}_1^2 + 4\hat{\rho}_2})$ , and hence estimates of their absolute values. The standard errors associated with the estimates of the absolute values of the roots can be obtained by making use of the method described by Klein [63, p. 258]. It is then possible to test directly the null hypothesis that the absolute value of each root equals unity against the alternative that it is less than unity.

## CHAPTER FIVE

### THE DATA

#### 5.1 Introduction

Having outlined the empirical approach to be adopted in this study, it is now necessary to consider the data problems which are involved in this approach. We begin in section 5.2 with a discussion of the various ways in which the excess demand for labour can be proxied. Definitions of the variables and the sources of data used are described in section 5.3 and an evaluation of the data is presented in that section where appropriate. Section 5.4 consists of a discussion of the "alignment problem" associated with the definition of variables in econometric work of the type to be undertaken in this study. Finally, in section 5.5 the treatment of seasonality is briefly considered. Two appendices which appear at the end of the thesis are related to the contents of this chapter. Appendix II summarizes the sources of the data and provides certain other related information. Appendix III contains a full listing of all the time series used in the estimations which are reported in Chapter Six.

#### 5.2 Excess Demand for Labour Proxies

It has been noted previously<sup>1</sup> that the term  $f(u_t)$  appears in the wage equation of a prototype expectations-hypothesis model as

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1. See above, p. 29n.



a proxy for the excess demand for labour. The unemployment rate  $u_t$  is, however, only one of a number of proxies which might be used. In fact, two other proxies were used in this study - the ratio of constant-price gross domestic product to its full employment level and the Dow-Dicks-Mireaux [21] excess demand for labour index.<sup>2</sup>

The use of the unemployment rate  $u_t$  as a proxy for the excess demand for labour is well established in the literature and fairly straightforward. The only matter which requires discussion is the selection of specific forms for the functions  $f(u)$  and  $\psi(u, \bar{u})$  which satisfy the restrictions imposed in Chapter Two.<sup>3</sup> The restrictions on  $f(u)$  are  $f'(u) < 0$ ,  $f''(u) > 0$ , and  $f(\bar{u}) = 0$  for some  $\bar{u} > 0$ . Possible forms for  $f(u)$  are (i) the linear form  $f(u) = a_0 + a_1 u$ , (ii) the reciprocal form  $f(u) = a_0 + a_1 u^{-1}$  and

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2. Another proxy which is sometimes used but which was rejected for the purposes of this study is the difference between the vacancy rate and the unemployment rate. Examples of the use of this excess-demand-for-labour proxy in the Australian literature are Pitchford [110], Parkin [91] and Challen and Hagger [13]. A related measure is the *ratio* of the vacancy rate to the unemployment rate which has been used for Australia by Higgins [47] and by Jonson, Mahar and Thompson [60]. The reason for the rejection of the vacancy rate-unemployment rate difference lies in the deficiencies of the available vacancies statistics for Australia. The published statistics are Vacancies Registered with the Commonwealth Employment Service which appear in ABS *Employment and Unemployment*, Reference 6.4. The coverage of these statistics is open to question because the extent of registration of job vacancies by employers is not known. Furthermore, there is no incentive to employers to notify their vacancies other than the desire to have them filled. It is likely therefore that registration of vacancies will be low when unemployment is high because employers will realize that positions can be filled easily. Accordingly, the proportion of all vacancies which are registered is itself likely to vary with labour market conditions, thereby bringing into question the reliability of the vacancies statistics. It is an explicit recognition of these deficiencies of published vacancies statistics which motivates (at least in part) the approach of Dow and Dicks-Mireaux in the development of their excess-demand-for-labour index. See below, pp. 133-136.

3. See above, p. 22 and p. 49.

(iii) the logarithmic form  $f(u) = a_0 + a_1 \ln u$ . All three forms have appeared in the literature. The linear form satisfies the first derivative restriction  $f'(u) < 0$  when  $a_1$  is negative but can not meet the second derivative restriction  $f''(u) > 0$  because its linearity implies that the second derivative is always zero. The intercept restriction,  $f(\bar{u}) = 0$  for some  $\bar{u} > 0$ , is met when  $a_0$  is positive, the intercept  $\bar{u}$  being  $-a_0/a_1$ . The derivatives of the reciprocal form are  $f'(u) = -a_1 u^{-2}$  and  $f''(u) = +2a_1 u^{-3}$ . The sign restrictions on the derivatives are therefore satisfied in the case of the reciprocal form when  $a_1$  is positive. The intercept restriction is met when  $a_0$  is negative, the  $\bar{u}$  intercept being  $-a_1/a_0$ . In the case of the logarithmic form the required derivatives are  $f'(u) = a_1 u^{-1}$  and  $f''(u) = -a_1 u^{-2}$  and the restrictions on them are met when  $a_1$  is negative. There is no sign restriction on  $a_0$  because the  $\bar{u}$  intercept for the logarithmic form is  $e^{-a_0/a_1}$  which is always positive as required.

Of the three forms for  $f(u)$ , the reciprocal form has appeared most commonly in the literature. The logarithmic form is an equally acceptable alternative. The linear form is inadequate, however, because it does not permit the required sign on the second derivative. Accordingly it was rejected for the purposes of this study. Preliminary experimentation with the reciprocal and logarithmic forms showed their performance to be very similar, with the reciprocal form performing slightly better in terms of goodness of fit. This being the case, the logarithmic form was dropped and in all cases in which the excess demand for labour was proxied by the unemployment rate  $f(u_t)$  was replaced in the wage equation by  $a_0 + a_1 u^{-1}$ . The same three general forms are available for  $\psi(u, \dot{u})$

and the reciprocal form

$$\psi(u, \dot{u}) = a_0 + a_1 u^{-1} + a_2 \dot{u}^{-1}$$

was again adopted. The restrictions<sup>4</sup> on  $\psi(u, \dot{u})$  are  $\psi_1 < 0$ ,  $\psi_{11} > 0$ ,  $\psi_2 < 0$  and  $\psi(\bar{u}, 0) = 0$  for some positive  $\bar{u}$ . The required derivatives of the reciprocal form of  $\psi(u, \dot{u})$  are  $\psi_1 = -a_1 u^{-2}$ ,  $\psi_{11} = +2a_1 u^{-3}$  and  $\psi_2 = -a_2 \dot{u}^{-2}$ , the sign restrictions being satisfied when both  $a_1$  and  $a_2$  are positive. Given that  $a_1$  is positive, the intercept restriction is satisfied when  $a_0$  is negative, the intercept  $\bar{u}$  being  $-a_1/a_0$ .

The use of the ratio of constant price gross domestic product to its full employment level as a proxy for the excess demand for labour is less straightforward. The difficulty lies in the need to measure full employment GDP. The usual solution to this problem<sup>5</sup> is to equate full employment GDP with the trend level of constant price GDP. This method was adopted here. Specifically, a trend of the form

$$Y_t = ae^{bt}, \quad (5.1)$$

where  $Y_t$  denotes Gross Domestic Product at average 1966-67 prices<sup>6</sup> and  $t$  denotes time in quarters measured from the base  $t = 1$  in 1959(3), was fitted<sup>7</sup> using OLS after taking natural logarithms. Denoting the

4. See above, p. 49.

5. This was the approach adopted by Laidler [69], for instance.

6. The source was ABS, *Quarterly Estimates of National Income and Expenditure*, Reference No. 7.10. Seasonally adjusted data was used, see below, p.

7. The linear form  $Y_t = a + bt$  was also tried. Although the results were very similar to those obtained using (5.1), the linear form gave a marginally poorer fit.

resulting OLS estimates of  $a$  and  $b$  by  $\hat{a}$  and  $\hat{b}$  respectively, the full employment level of GDP, denoted by  $Y^*$ , was computed from

$$Y_t^* = \hat{a} e^{\hat{b}t} \quad (5.2)$$

Finally, the ratio of constant price GDP to its full employment level, denoted by  $y$ , is defined as

$$y_t = \frac{Y_t}{Y_t^*} \quad (5.3)$$

The derivative and intercept restrictions on the function  $f(\cdot)$  when the excess-demand-for-labour proxy is the unemployment rate derive from a theoretical argument concerning the relationship between labour excess demand and the unemployment rate.<sup>8</sup> No such argument exists linking the ratio of constant price GDP to its full employment level with labour excess demand. Accordingly, there is no theoretical justification for adopting a particular functional form when entering  $y$  as a labour excess demand proxy in the wage equation and for this reason  $y$  was entered linearly as  $a_0 + a_1 y$ .

The excess demand for labour is zero when constant price GDP is at its full employment level, that is, when  $Y = Y^*$  or  $y = 1$ . When constant price GDP is higher than its full employment level ( $y > 1$ ), the excess demand for labour will be positive and will be greater the higher is constant price GDP relative to its full employment level. This being the case the excess demand for labour is an increasing function of the ratio of constant price GDP to its full employment level. The derivative restrictions on  $f(u)$  and

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8. See, for example, Lipsey [71] especially pp. 12-19, and Phelps [106] especially pp. 146-149.

$\psi(u, \dot{u})$  are based on the premise that  $w$  is an increasing function of the excess demand for labour. Applying this premise directly to the current situation, it follows that  $a_1$  can be expected *a priori* to be positive.

A level and change form, analogous to  $\psi(u, \dot{u})$  is also required when the excess-demand-for-labour proxy is the ratio of constant price GDP to its full employment level. This was also chosen to be linear, the form being<sup>9</sup>  $a_0 + a_1 y + a_2 \Delta y$ . It can again be expected *a priori* that  $a_1$  will be positive because, other things being equal, the excess demand for labour is an increasing function of the ratio of constant price GDP to its full employment level and, as before,  $w$  is an increasing function of the excess demand for labour. Further, the change in the excess demand for labour will be an increasing function of the change in the ratio of constant price GDP to its full employment level and, other things being equal,  $w$  will be greater the larger the change in labour excess demand. Accordingly, it can be expected *a priori* that  $a_2$  will also be positive.

The final proxy used for the excess demand for labour was the Dow and Dicks-Mireaux (DDM) index. The DDM index has been calculated for Australia for the period 1947(3) to 1963(2) by Hagger [41] and extended to the period 1947(3) to 1972(1) by Hagger and Rayner [42]. Hagger in fact presents twenty-one index series in all, one for each of the States and for Australia as a whole and in each case a separate index for males and females. However, only

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9.  $\Delta y$  denotes the first difference of  $y$  and is defined by  $\Delta y_t = y_t - y_{t-1}$ . See below, p. 144.

one of these series, that relating to Australia as a whole, is extended by Hagger and Rayner. This series they denote by EDL I. A related series, denoted by EDL II, is also presented by Hagger and Rayner. Both series will be employed here. Before attempting a description of the two EDL series, it is convenient to dispose of the questions of the way in which EDL was entered into the wage equations and the *a priori* signs of the parameters involved. EDL was entered into the wage equations linearly - as  $a_0 + a_1 \text{EDL}$  in its level only form and as  $a_0 + a_1 \text{EDL} + a_2 \Delta \text{EDL}$  in its level and change form. Invoking the premise that  $w$  is an increasing function of the excess demand for labour and of the change in the excess demand for labour, it follows *a priori* that  $a_1$  and  $a_2$  will both be positive.

The two main features of the DDM method<sup>10</sup> are the treatment of labour market "maladjustment" and the explicit recognition of the existence of "statement error" in registered vacancies statistics. Maladjustment is defined as the number of registered vacancies or the equal number of registered unemployed consistent with zero excess demand for labour. If registered vacancies were equal to the true number of vacancies then, when positive, the percentage excess demand for labour would be measured by

$$100 \left( \frac{V - M}{E} \right)$$

where  $V$  denotes registered vacancies,  $E$  denotes employment and  $M$  denotes maladjustment. On the other hand, when negative, the percentage excess demand for labour would be measured by

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10. See Dow and Dicks-Mireaux [21] and Hagger [41], especially pp. 28-32.

$$100 \left( \frac{M - U}{E} \right)$$

where  $U$  denotes registered unemployed. It is recognized, however, that registered vacancies will not in general accurately reflect true vacancies. To account for this deficiency of registered vacancies statistics, the expression for percentage excess demand for labour when positive<sup>11</sup> is modified to

$$100 \left( \frac{\frac{V}{s} - M}{E} \right)$$

where  $s$  denotes the statement error and is defined as the ratio of registered vacancies to true vacancies. Denoting registered vacancies, registered unemployment and maladjustment, each as a ratio of employment, by  $v$ ,  $u$  and  $m$  respectively, the expression for positive percentage excess demand for labour can be written as

$$100 \left( \frac{v}{s} - m \right)$$

and the expression for negative percentage excess demand for labour as

$$100(m - u)$$

Positive excess demand is said to exist in those periods for which true vacancies exceeds the number of vacancies consistent with zero excess demand and registered unemployed is less than the number of registered unemployed at zero excess demand. It can then be shown<sup>12</sup>

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11. No modification is required in the case of the expression for percentage excess demand for labour when negative because registered vacancies does not appear there.

12. See Hagger [41], p. 29.

that positive excess demand exists in a period if  $\frac{v}{s} > u$ . Similarly, zero excess demand exists when  $\frac{v}{s} = u$  and negative excess demand when  $\frac{v}{s} < u$ .

To overcome the problem of  $m$  and  $s$  being unobservable, the DDM method assumes that the following relationship holds<sup>13</sup>

$$s = \frac{uv}{m^2}$$

It is further assumed that *one* of  $s$  or  $m$  is constant. If the "constant  $s$  approach" is adopted, external evidence is used to identify a period of zero excess demand and an estimate of  $s$  obtained from<sup>14</sup>  $s = \frac{v}{u}$ . An estimate can then be obtained for  $m$  for any given period by solving in  $s = \frac{uv}{m^2}$ . On the other hand, if the alternative "constant  $m$  approach" is opted for, a period of zero excess demand is again identified and an estimate of  $m$  obtained from  $m = u$ . In this case,  $s$  can then be calculated for any given period from  $s = \frac{uv}{m^2}$ . The choice between the two approaches is made on the basis of the characteristics of the particular case in hand.<sup>15</sup>

The case of current interest is the DDM index for Australia as a whole. The constant  $m$  approach was selected in this case. The value of  $m$  used was 0.0222, this being an average of the  $u$  observations for the December quarters of 1957 and 1958. These two quarters were identified as periods of approximately zero excess demand on the basis of evidence about employment and hours of work. With  $m = 0.0222$ ,

13. See Hagger [41], p. 30 for the justification.

14. Recall that  $v/s = u$  in periods of zero excess demand.

15. See Hagger [41], pp. 33-34 for details.



s was calculated for each quarter of the sample period from  $s = \frac{vu}{m}$ . Finally, percentage excess demand for labour was calculated for each quarter from  $100(\frac{v}{s} - m)$  when  $\frac{v}{s} > u$  and from  $100(m - u)$  when  $\frac{v}{s} < u$ . The resulting excess demand for labour series<sup>16</sup> is referred to as EDL I. The second excess demand for labour series,<sup>17</sup> EDL II, is a weighted average of the EDL I series, the relationship between them being  $(EDL II)_t = 0.75(EDL I)_t + 0.25(EDL I)_{t-1}$ . Hagger and Rayner [42, p. 180] argue that the EDL II series is better aligned than the EDL I series. Both series were used in the empirical work reported in Chapter Six.

### 5.3 Sources of Data and Definitions

For the purposes of the proposed empirical analysis, quarterly time series are required for  $p$ ,  $w$ ,  $u$ ,  $\dot{u}$ , EDL I, EDL II,  $\Delta EDL I$ ,  $\Delta EDL II$ ,  $y$ ,  $\Delta y$ . The objective of the current section is to describe the definitions of these variables in terms of published statistics and the sources of the data. Remarks will also be made concerning the adequacy of the data, where appropriate.

The variable  $p$  was defined in Chapter Two as the percentage rate of change of prices. The time series for  $p$  was obtained from<sup>18</sup>

$$p_t = \frac{P_t - P_{t-4}}{P_{t-4}} \cdot 100$$

where  $P_t$  denotes the appropriate price index in quarter  $t$ . In this

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16. See Hagger and Rayner [42], Table V, p. 179.

17. *ibid.*

18. This definition is a consequence of the decision taken in section 5.4 below in relation to the treatment of seasonality.

context a price index can be considered appropriate if (i) it measures the prices of goods and services which comprise the expenditure of the households of wage and salary earners and (ii) it is well-publicized. The latter requirement arises because inflationary expectations are revised in the prototype models solely on the basis of the behaviour of the actual inflation rate. It is this second requirement that effectively governs the choice of the appropriate price index because the only Australian price index which is widely publicized is the Consumer Price Index.<sup>19</sup> The Consumer Price Index meets the first requirement well in view of the statement of the Commonwealth Statistician that "The Consumer Price Index is a quarterly measure of variations in retail prices for goods and services representing a high proportion of the expenditures of urban wage-earner households."<sup>20</sup> The implicit deflator of Consumption Expenditure represents an alternative price index on the basis of the first requirement but, by its implicit nature, must be rejected on the basis of the second requirement.

The variable  $w$ , the percentage rate of change of money wage costs per man, is defined in an analogous fashion to  $p$  as

$$w_t = \frac{W_t - W_{t-4}}{W_{t-4}} \cdot 100$$

where  $W_t$  denotes the appropriate index of money wage costs per man in quarter  $t$ . The only requirement for an index of money wage costs per man to be appropriate is that it be sufficiently readily available

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19. The series is Consumer Price Index, All Groups, Six Capitals and the source is ABS, *Consumer Price Index*, Reference No. 9.1.

20. CBCS, *Labour Report* No. 57 1972, Reference No. 6.7, p. 7.

for employers to have easy access to it. The latter requirement again arises because, given the structure of the prototype models, wage-inflation expectations are formed by employers solely on the basis of the behaviour of the actual rate of wage-inflation. There are three main candidates for the index of money wage costs per man: the published indexes Weekly Wage Rates and Average Weekly Earnings<sup>21</sup> and an index which can be calculated from published statistics, namely the ratio of Wages, Salaries and Supplements<sup>22</sup> to Employment.<sup>23</sup>

Weekly Wage Rates specifically excludes several of the components of wage costs which the definition of W includes. The two major items are over-award payments<sup>24</sup> and overtime. Other components of wage costs which Weekly Wage Rates excludes are annual leave loadings, retrospective payments of wages and loadings which are not applicable to all workers under a specified award. Payments to part-time and junior employees are also not covered. A further deficiency is that no rates applicable to salaried workers are included. Weekly Wage Rates was therefore rejected on the grounds that it does not cover several important components of wage costs.

The Commonwealth Statistician states in relation to Average Weekly Earnings Per Employed Male Unit that "The earnings figures used in the calculation of the averages comprise award and over-award

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21. ABS, *Wage Rates and Earnings*, Reference No. 6.16.

22. Available from ABS, *Quarterly Estimates of National Income and Expenditure*, Reference No. 7.5.

23. The appropriate Employment series is Civilian Employees and Defence Forces: Australia available from ABS, *Employment and Unemployment*, Reference No. 6.4.

24. Weekly Wage Rates relates to *minimum* wage rates for adult males and females.

wages and salaries, the earnings of employees not covered by awards, overtime earnings, bonuses and allowances, commissions, directors' fees and payments made retrospectively or in advance during the quarter. Earnings of part-time as well as full-time employees, and of juniors as well as adults, are included."<sup>25</sup>

The coverage of Average Weekly Earnings is therefore very close to what is required. Some minor components of wage costs, such as superannuation contributions by employers and meal allowances, are not covered but their omission is not likely to be of any importance. Average Weekly Earnings also meets the availability requirement well in view of the regular publicity which it receives and its appearance in several of the well-known publications of the Australian Bureau of Statistics.<sup>26</sup>

The coverage of Wages, Salaries and Supplements is very similar to that of Average Weekly Earnings. The Commonwealth Statistician describes Wages, Salaries and Supplements as "Payments in the nature of wages and salaries as defined for pay-roll tax, including allowances for income in kind (Board and quarters, etc.), together with supplements to wages and pay and allowances of members of the forces ... Supplements consist of employers' contributions to pension and superannuation funds, direct payments and retiring allowances by employers and amounts paid as workers' compensation for injuries."<sup>27</sup> This description suggests that the coverage of

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25. ABS, *Wage Rates and Earnings*, February 1975, Reference No. 6.16, p. 20.

26. In addition to being published in *Wage Rates and Earnings*, it appears in the *Digest of Current Economic Statistics*, the widely circulated *Quarterly Summary of Australian Statistics*, the *Monthly Review of Business Statistics* and is frequently reported in the Australian Treasury's *Round-up of Economic Statistics*.

27. ABS, *Quarterly Estimates of National Income and Expenditure*, December Quarter 1974, Reference No. 7.5, p. 35.

Wages, Salaries and Supplements is a little better than that of Average Weekly Earnings in that Supplements includes some (albeit minor) components of wage costs which were excluded from Average Weekly Earnings. Unfortunately, an index of money wage costs per man based on Wages, Salaries and Supplements falls down badly on the availability requirement because it is not readily accessible to the layman employer and requires a ratio calculation.<sup>28</sup> Accordingly Average Weekly Earnings per Employed Male Unit was adopted as the index of money wage costs per man.

The available time series for Average Weekly Earnings contains a break in continuity between the June and September quarters of 1966, which is the result of the change in the definition of the labour force brought in at the June 1966 Population Census. The Australian Bureau of Statistics has produced estimates of Average Weekly Earnings on the basis of the new definition for the period September quarter 1961 to June quarter 1966. Using these estimates and the old series for the period up to the June quarter 1961, the break in continuity occurs between the June and September quarters of 1961. In terms of  $w$ , the percentage rate of change of Average Weekly Earnings, the effect of the break in continuity is to introduce a distortion into the observations for the September and December quarters of 1961 and for the March and June quarters of 1962. The magnitude of the distortion in  $w$  is not likely to be very great and no attempt was made to eliminate it.

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28. Note however that the Wages, Salaries and Supplements based index is appropriate in Model A where wage inflation expectations do not appear and hence the availability requirement is not relevant. Despite this remark, the Wages, Salaries and Supplements based index was not used on the grounds that it is desirable for comparability that the same  $W$  index be used throughout the empirical work. In any event, Jonson, Mahar and Thompson [60, p. 84] state that very similar results are obtained from Average Weekly Earnings and Wages, Salaries and Supplements divided by non-farm employment.

The unemployment rate,  $u$ , is defined as

$$u_t = \frac{U_t}{U_t + E_t} \cdot 100$$

where  $U_t$  denotes unemployment and  $E_t$  denotes employment. Two unemployment series are available for Australia. These are Registered Unemployed which "Comprises all persons who were ... registered with the Commonwealth Employment Service ... at the Friday nearest the end of the month, who claimed when registering that they were not employed, and who were seeking full-time employment..."<sup>29</sup> and Unemployed Persons which is obtained from the Quarterly Population Survey conducted by the Australian Bureau of Statistics. There is little to choose between the two unemployment series on *a priori* grounds. However, the Labour Force Survey section of the Quarterly Population Survey has been conducted for the whole of Australia<sup>30</sup> only since 1964. Thus the length of the Unemployed Persons time series is quite short, consisting of about forty observations. After allowing for the required lagged unemployment variables, fewer observations still remain in the effective sample period. In view of the fact that nothing is known about the small sample properties of the NLLS estimator and that the asymptotic properties have been established,<sup>31</sup> it is important that the time series be as long as possible, fifty observations usually being considered a minimum when asymptotic properties are relied upon.

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29. ABS, *Employment and Unemployment*, April 1975, Reference No. 6.4, p. 13. This publication is also the source of both unemployment series.

30. See ABS, *Labour Report*, No. 57 1972, Reference No. 6.7, p. 170.

31. See above, pp. 116-117.

Accordingly Registered Unemployed was adopted for the unemployment variable, there being no difficulty in obtaining a time series of the required length. School-leavers were excluded on the grounds that their annual entry into the labour force has a noticeable effect on Registered Unemployed but is unlikely to affect the rate of wage-inflation to any appreciable extent.

The employment series used is Civilian Employees, Persons: Australia.<sup>32</sup> Defence Forces were excluded in order to produce comparability with the unemployment series. The Commonwealth Statistician excludes employees in agriculture from Civilian Employees<sup>33</sup> so that the series used might better be described as Non-farm civilian employment. The coverage of Civilian Employees is very closely comparable with that of Average Weekly Earnings. Average Weekly Earnings relates to civilians only<sup>34</sup> and since it is based mainly on data declared in payroll tax returns relatively few employees in agriculture will be included.<sup>35</sup>

Both the Civilian Employees and Average Weekly Earnings series include a break in continuity between the June and September quarters of 1971. This was the result of a change in the treatment

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32. The source is ABS, *Employment and Unemployment*, Reference No. 6.4.

33. See ABS, *Employment and Unemployment*, April 1975, Reference No. 6.4, p. 2.

34. See ABS, *Labour Report*, No. 57 1972, Reference No. 6.7, p. 103.

35. It is generally accepted that most Australian farms are organized as unincorporated enterprises based on a family unit. Accordingly very few are likely to be subject to payroll tax.

of trainee teachers at the 1971 Population Census. At that census trainee teachers were classified for the first time as being outside the labour force. The effect of the break in continuity is not likely to be appreciable.<sup>36</sup>

The three variables EDL I, EDL II and  $y$  have already been discussed in the previous section.<sup>37</sup> The two EDL series were obtained directly from Hagger and Rayner.<sup>38</sup> The  $y$  series was obtained from

$$y_t = \frac{Y_t}{Y_t^*}$$

where seasonally adjusted Expenditure on Gross Domestic Product at Average 1966-67 prices<sup>39</sup> was used for  $Y$  and  $Y^*$  was calculated from

$$Y_t^* = 3876.8e^{0.01239t}$$

where the time unit for  $t$  was a quarter and the base  $t = 1$  for 1959(3). As was explained above<sup>40</sup> this expression is obtained by fitting an exponential trend to the  $Y$  series by OLS.

The only remaining variables are the change variables,  $\dot{u}$ ,  $\Delta$ EDL I,  $\Delta$ EDL II and  $\Delta y$ . The definition of  $\dot{u}$  is

36. See ABS, *Labour Report*, No. 57 1972, Reference No. 6.7, p. 173 and p. 104.

37. See above, pp. 130-131 and 133-136.

38. [42], Table V, p. 179.

39. The source is ABS, *Quarterly Estimates of National Income and Expenditure*, Reference No. 7.10.

40. See p. 130.



$$\dot{u}_t = \frac{u_t - u_{t-1}}{u_{t-1}} \cdot 100$$

where  $u$  is the unemployment rate defined above.<sup>41</sup> As an example of the way in which the other three change variables were defined, the definition of  $\Delta y$  is

$$\Delta y_t = y_t - y_{t-1}$$

where  $y_t$  is as defined above. The definition of  $\dot{u}$  is the conventional one and is adopted solely for that reason. Because  $y$  is effectively an index whose base is 1.000 there is very little difference between  $\Delta y_t = y_t - y_{t-1}$  and  $\dot{y}_t = (y_t - y_{t-1})/y_{t-1}$  and as such the computationally simpler  $\Delta y$  is adopted.

#### 5.4 The Alignment Problem

The alignment problem arises whenever it is necessary to regress (or otherwise relate) a rate of change variable on a level variable. The problem was first discussed<sup>42</sup> by Bowen and Berry [6] in terms of the regression of the annual rate of change of money wages on the level of unemployment. They saw the alignment problem in the following terms. "Given [the] data situation, ... what expression for the annual rate of change of money wages ( $\dot{W}$ ) is to be related to what expression for the level of unemployment ( $U$ )..." [6, p. 171]

The situation of current interest is one in which a quarterly percentage rate of change such as  $w$ , defined by

41. See p. 141.

42. As far as can be ascertained, this is still the only published consideration of the alignment problem.

$$w_t = \frac{W_t - W_{t-4}}{W_{t-4}}$$

where  $W$  is the index of money wage costs per man, is to appear in regressions with the level variable  $u$ , the unemployment rate. In both cases, the time unit and the time series on the variables are quarterly. Before describing the nature of the alignment problem in this context it is necessary to establish the association of the variables  $W_t$  and  $u_t$  with instants or intervals of time.

The unemployment series used is Registered Unemployed<sup>43</sup> which reflects the number registered as unemployed at the end of the month.<sup>44</sup> Taking the observation for the last month of the quarter to obtain the quarterly series, it is apparent that the unemployment series represents conditions at the end of the quarter or that  $u_t$  is properly associated with the time instant marking the end of quarter  $t$ .

The index of money wage costs used is Average Weekly Earnings.<sup>45</sup> The main source of original data used in the compilation of Average Weekly Earnings is Payroll Tax Returns<sup>46</sup> which employers are required to lodge monthly. It follows that the index of money wage costs used represents an average of conditions existing over the quarter and  $W_t$  is therefore properly associated with the interval

43. See above, pp. 141-2.

44. See above, p. 141.

45. See above, pp. 138-9.

46. See ABS, *Wage Rates and Earnings*, February 1975, Reference No. 6.16, p. 20 where it is stated *inter alia* that payroll tax returns and direct returns from government and other bodies account for about 90 per cent of all employees covered by Average Weekly Earnings.

of time comprising quarter  $t$ . In view of this observation, the effect of the definition  $w_t = (W_t - W_{t-4})/W_{t-4}$  is to produce a  $w_t$  which is not associated just with the time instant  $t$ , as its subscript might suggest, but one which is more correctly associated with the time interval commencing at the beginning of quarter  $(t - 4)$  and finishing at the end of quarter  $t$ . The centre of this time interval is at the mid-point of quarter  $(t - 2)$ . The interval in question is shown as the bold line in Figure 5.1.

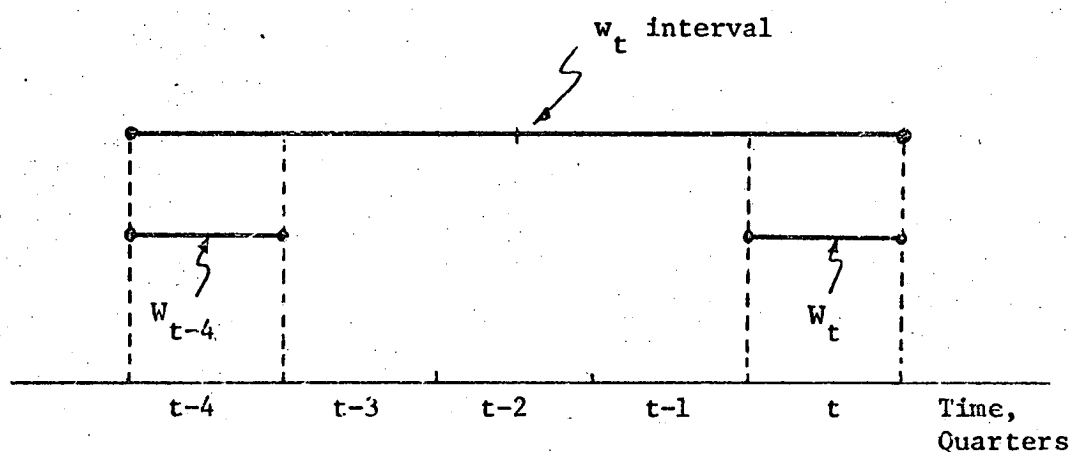


Figure 5.1

The association of  $w_t$  with the interval spanning the entirety of quarters  $(t - 4)$ ,  $(t - 3)$ ,  $(t - 2)$ ,  $(t - 1)$  and  $t$  presents a problem when the variable  $w$  appears in regressions with other variables whose time subscripts are ostensibly the same. For instance, suppose that  $w_t$  is regressed on  $u_t$  (among other regressors perhaps). For reasons which were discussed earlier,<sup>47</sup>  $u_t$  is associated with an instant of time, the end of quarter  $t$ . However, as was just shown,

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47. See above, p. 145.

$w_t$  is associated with the interval of time spanning quarters  $(t - 4)$  through to  $t$ . The implication is that the adoption of the definition of  $w_t$  results in a pseudo-lead of  $u_t$  ahead of  $w_t$ , in that the time instant associated with  $u_t$  is two and a half quarters ahead in time of the centre of the interval associated with  $w_t$ . Furthermore and more importantly, the information in  $w_t$  is not collected over the same time interval as the information in  $u_t$ .

The alignment problem is seen here as the problem of finding suitable definitions of all the variables in the regression which meet the following two criteria: (i) that the information contained in the variables is collected over the same intervals of time and (ii) that the centres of the intervals should coincide.<sup>48</sup> The existence of the second criterion implicitly recognizes that it is not always possible to fully satisfy the first. It is also likely that in most cases it will not be possible to meet either criterion completely. Accordingly, in many cases there is no perfect solution to the alignment problem.

The solution to the alignment problem which is adopted in this study is to redefine the variable  $u_t$  in such a way as to associate it with a time interval as close as possible to that which results from the definition of  $w_t$ . Although not altogether satisfactory, the usual method of alignment<sup>49</sup> is to use a four-quarter

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48. No such criteria are mentioned by Bowen and Berry [6]. It is fairly clear, however, that they concentrate on a consideration analogous to criterion (ii).

49. This method is used, for example, by Parkin [91], by Jonson, Mahar and Thompson [60], by Perry [98] and by Solow [120].



of which is involved in  $w$ . It is, however, otherwise associated with and centred about the same time interval as  $w$ . The six-quarter moving average also suffers from the practical drawback that it is inconsistent with the treatment of seasonality adopted.<sup>50</sup> The other alternative method of alignment is a four-quarter moving average lagged one quarter, i.e.  $\frac{1}{4}(u_{t-1} + u_{t-2} + u_{t-3} + u_{t-4})$ . While the interval associated with this aligned  $u$  is centred at the same point as the  $w$  interval, the interval in question is shorter by one quarter at each end, starting at the end of quarter  $(t - 5)$  and finishing at the end of quarter  $(t - 1)$ . Although not suffering from the practical drawback of the six-quarter moving average, it makes no use of information from quarter  $t$ . This failure to incorporate any of the contemporaneous information used by  $w$  (i.e. information from quarter  $t$ ) is a very serious deficiency. It is apparent that the cost of removing the *pseudo*-lead of the centre of the  $u4QMA$  interval ahead of the centre of the  $w$  interval is the introduction of an *actual* lag in the most recent information involved in  $u$  behind that involved in  $w$ .

While it is recognized that the  $u4QMA$  method of alignment is not a perfect one, it has been shown to be superior to the available alternatives and is therefore adopted throughout the empirical work undertaken in this study. Thus the quarterly percentage rates of change  $p$  and  $w$  are defined respectively by

$$p_t = \frac{P_t - P_{t-4}}{P_{t-4}} \cdot 100$$

and

$$w_t = \frac{W_t - W_{t-4}}{W_{t-4}} \cdot 100$$

where  $P$  and  $W$  denote the price index and index of money wage costs

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50. See section 5.4 below.

per man respectively. All other variables are aligned by means of a four-quarter moving average of the original variable, that is, in a manner analogous to the alignment of  $u$ :

$$u4QMA_t = \frac{1}{4}(u_t + u_{t-1} + u_{t-2} + u_{t-3})$$

### 5.5 Treatment of Seasonality

Quarterly time series are used in all estimations undertaken in this study. It can be expected, therefore, that some or all variables will be subject to seasonal influence. There are two main approaches to the treatment of seasonality. One approach is to take explicit account of seasonal influence by introducing seasonal dummy variables. The main advantage of this approach is that it is possible to undertake tests of hypotheses concerning the extent of seasonal influence. The drawbacks of the method are the loss of degrees of freedom and the increase in computation.<sup>51</sup> The other approach is to eliminate the seasonal influence by deseasonalizing the variables prior to estimation. The treatment of seasonality adopted for the purposes of this study is in the spirit of the second approach. The seasonal influence is effectively removed through the definitions of the percentage rate of change variables in terms of the change from the same quarter of the previous year and through the alignment of all other variables using a four-quarter moving average.<sup>52</sup> Any remaining seasonal influence will

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51. Increased computation is not usually an important factor when OLS estimation is undertaken. It becomes important, however, when iterative estimation methods, such as the NLLS estimator used in this study, are used.

52. This approach to the treatment of seasonality was used successfully by Jonson, Mahar and Thompson [60], by Parkin [91] and by Solow [120, p. 8].

manifest itself as fourth-order autocorrelation in the estimation residuals. Such autocorrelation can be detected and treated using the approach outlined in section 4.4 above.

In view of the treatment of seasonality adopted, all data is seasonally unadjusted. There are, however, two important exceptions to this rule. In the case of the variables EDL I and EDL II the source data from Hagger and Rayner [42] was seasonally adjusted and unadjusted data is not available. As such seasonally adjusted data had to be used for the EDL variables. The other exception where seasonally adjusted data was used instead of unadjusted data was in the case of  $y$ , the ratio of constant price GDP to its full employment level. It will be recalled that the full employment level of constant price GDP is equated with the trend value of constant price GDP, the latter value being obtained by fitting by OLS an exponential curve of the form  $ae^{bt}$  to the constant price GDP series. If unadjusted data was used in fitting the trend, the estimates of  $a$  and  $b$  would be biased by the seasonal influence. In turn, the  $Y^*$  values would be biased and this bias would flow through to the  $y$  series. To avoid this eventuality, seasonally adjusted data was used for the ratio of constant price GDP to its full employment level.

Reiterating, in the case of EDL I, EDL II and  $y$  the data was seasonally adjusted. In all other cases, unadjusted data was used.



## CHAPTER SIX

### ESTIMATION RESULTS - PROTOTYPE MODELS

#### 6.1 Introduction

Two prototype expectations-hypothesis models, designated Model A and Model B, were discussed in Chapter Two. In each case two versions were presented, Models A.1 and B.1 being the versions in which the relevant expectations variable enters the wage equation with a unitary coefficient, and Models A.2 and B.2, the versions in which that coefficient is a positive fraction. These four models were modified in various ways during the course of the discussion of Chapter Four to facilitate the proposed empirical testing of the expectations hypothesis with reference to the Australian economy. A further extension was introduced in Chapter Five in that four separate proxies for the excess demand for labour were proposed.

The plan of the current chapter is as follows. The first objective is to obtain estimates of the structural coefficients of each of the four models using the reduced form approach, the non-linear least squares (NLLS) estimator and the method of treatment of autocorrelation described in Chapter Four. In each case, eight separate sets of estimates of the structural coefficients will be produced, corresponding to the eight forms of  $f(u)$  or  $\psi(u, \dot{u})$  distinguished in Chapter Five. For instance, for Model A.1 there will be a set of eight NLLS estimates of the structural coefficients, one corresponding to each of  $a_0 + a_1 u^{-1}$ ,  $a_0 + a_1(\text{EDL I})$ ,  $a_0 + a_1(\text{EDL II})$ ,  $a_0 + a_1 y$ ,  $a_0 + a_1 u^{-1} + a_2 \dot{u}^{-1}$ ,  $a_0 + a_1(\text{EDL I}) + a_2 \Delta(\text{EDL I})$ ,

$a_0 + a_1(\text{EDL II}) + a_2\Delta(\text{EDL II})$  and  $a_0 + a_1y + a_2\Delta y$ . The same applies to Models A.2, B.1 and B.2. For each of the four models, a preferred estimation will be selected from the eight available on the basis of the usual econometric criteria (to be described more fully below). This selection of the preferred estimation for each model can be looked upon as the device by which the most appropriate form of  $f(u_t)$ <sup>1</sup> was chosen for each of the four models A.1, A.2, B.1 and B.2. The final step is to select a preferred model by comparison of the preferred estimations for the individual models.

The eight sets of estimates of the structural coefficients of Model A.2 are described in Section 6.2 followed by the corresponding discussion for Model A.1 in Section 6.3. (Model A.2 is considered first because it is a less restrictive version of Model A than is Model A.1 and for this reason represents a more suitable vehicle for discussing certain general matters which apply to all estimations.) The eight sets of estimates of the structural coefficients of Models B.2 and B.1 are described in Section 6.4 and 6.5 respectively. Section 6.6 presents a comparison of the preferred estimations for the four models and includes some remarks regarding the selection of the preferred model. The short-run and long-run trade-offs between inflation and unemployment in Australia for the sample period, implied by the estimated form of the preferred model, are also considered in Section 6.6.

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1. As it is no longer necessary to distinguish  $f(u)$  and  $\psi(u, \dot{u})$ ,  $f(u)$  will be used hereafter where  $\psi(u, \dot{u})$  would otherwise have appeared.

## 6.2 Estimates of the Structural Coefficients of Model A.2

The structural form of Model A.2 when  $f(u_t) = a_0 + a_1 u_t^{-1}$  is as follows.

$$w_t = a_0 + a_1 u_t^{-1} + \delta p_t^e + \epsilon_{1t} \quad (6.1)$$

$$p_t^e = (\alpha + \gamma)p_{t-1} - \alpha p_{t-2} + (1 - \gamma)p_{t-1}^e + \epsilon_{2t} \quad (6.2)$$

where  $\epsilon_{1t}$  and  $\epsilon_{2t}$  are random disturbances. The equation for  $w_t$  in the reduced form of this system is

$$\begin{aligned} w_t = & a_0 \gamma + a_1 u_t^{-1} - a_1 (1 - \gamma) u_{t-1}^{-1} + (\alpha + \gamma) \delta p_{t-1} - \alpha \delta p_{t-2} \\ & + (1 - \gamma) w_{t-1} + V_t \end{aligned} \quad (6.3)$$

where  $V_t$  represents the disturbance term.<sup>2</sup>

Equation (6.3) was estimated by NLLS as it stands (in its fully restricted form) using the data described in Chapter Five. The sample period was 1958(3)-1974(4), comprising 66 observations. The resulting NLLS estimates, together with certain other relevant information associated with the estimation, is shown in Table 6.1.

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2. The structural form and the reduced form equation for  $w_t$  for the other forms of  $f(u_t)$  can be obtained by modifying (6.1) and (6.3). For instance, the structural and reduced forms when  $f(u_t)$  is replaced by  $a_0 + a_1(\text{EDL I})_t$  are obtained simply by replacing  $u^{-1}$  by EDL I everywhere. The structural form when  $f(u_t) = a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$  is found by adding the term  $+a_2 \dot{u}_t^{-1}$  to (6.1) while the reduced form equation for  $w_t$  is obtained by adding the terms  $+a_2 \dot{u}_t^{-1} - a_2(1 - \gamma)\dot{u}_{t-1}^{-1}$  to (6.3). The equations for the other forms of  $f(u_t)$  can then be obtained as before by replacing  $u^{-1}$  and  $\dot{u}^{-1}$  with the appropriate variables everywhere.

TABLE 6.1

NLLS Estimates of Equation (6.3)

NLLS Estimate of: <sup>a</sup>					MSR <sup>b</sup>
$a_0$	$a_1$	$\alpha$	$\gamma$	$\delta$	
-0.267 (0.067)	2.568 (0.601)	0.083 (0.409)	0.195 (1.643)	1.954 (2.688)	3.279

Correlogram of Residuals<sup>c</sup>

Lag, k $\hat{\psi}_k$	1	2	3	4	5	6
	0.108 (0.878)	-0.006 (0.049)	0.064 (0.520)	-0.396 (3.220)	-0.284 (2.309)	0.068 (0.553)
k $\hat{\psi}_k$	7	8	9	10	11	12
	-0.016 (0.130)	0.062 (0.504)	0.153 (1.244)	-0.157 (1.276)	-0.096 (0.780)	-0.192 (1.561)

- Notes:
- a. Figures in parentheses are absolute values of the asymptotic t-ratios. See above, p. 117.
  - b. MSR denotes mean square residual. See text, p. 155.
  - c. Figures in parentheses are absolute values of the approximate asymptotic t-ratios. See above, p. 120n.

It will be noted that in place of  $\bar{R}^2$ , the usual measure of goodness of fit, the mean-square-residual (MSR) is reported in Table I. MSR has been adopted as the basis of goodness of fit comparisons throughout this study because the usual properties of  $\bar{R}^2$  do not apply where the relationship being estimated is non-linear.

The correlogram of the residuals which appears in Table 6.1 is typical in that the only estimated autocorrelation coefficients

(correlogram ordinates) which are significantly different from zero at the 5 per cent level are those at lags 4 and 5.<sup>3</sup> The very strong autocorrelation at lag 4 suggests that a fourth-order autoregressive scheme may well be appropriate. That is, the following scheme is suggested for the disturbance  $V_t$  of (6.3):

$$V_t = \rho_4 V_{t-4} + \eta_t \quad (6.4)$$

where  $\eta_t$  is a random disturbance with the Classical properties.

Applying the Cochrane-Orcutt transformation<sup>4</sup> to equations (6.3) and (6.4) we get:

$$\begin{aligned} w_t = & a_0 \gamma (1 - \rho_4) + a_1 u_t^{-1} - a_1 (1 - \gamma) u_{t-1}^{-1} - a_1 \rho_4 u_{t-4}^{-1} + a_1 (1 - \gamma) \rho_4 u_{t-5}^{-1} \\ & + (\alpha + \gamma) \delta p_{t-1} - \alpha \delta p_{t-2} - (\alpha + \gamma) \delta \rho_4 p_{t-5} + \alpha_2 \delta \rho_4 p_{t-6} \\ & + (1 - \gamma) w_{t-1} + \rho_4 w_{t-4} - (1 - \gamma) \rho_4 w_{t-5} + \eta_t \end{aligned} \quad (6.5)$$

The NLLS estimates of equation (6.5) and the corresponding residuals correlogram are shown in Table 6.2. The correction for fourth-order autocorrelation has been partially successful in that the estimated autocorrelation coefficient at lag 4 is not significantly different from zero even at the 20 per cent level. The estimated autocorrelation coefficient at lag 5 is, however, slightly higher than before. The coefficient  $\rho_4$  of the postulated fourth-order autoregressive scheme

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3. The approximate asymptotic variance of the correlogram ordinates is  $T^{-1} = 0.015$  ( $T = 66$  in this case). See above, p. 120n. The corresponding standard error is therefore 0.123.

4. See above, p. 121.

TABLE 6.2

## NLLS Estimates of Equation (6.5)

NLLS Estimate of Parameter: <sup>a</sup>						MSR	99% Confidence Limits for $\rho_4$
$a_0$	$a_1$	$\alpha$	$\gamma$	$\delta$	$\rho_4$		
1.488 (0.569)	1.028 (0.325)	0.368 (1.311)	0.230 (1.946)	1.599 (3.858)	-0.448 (3.731)	2.694	-0.139 -0.757

Correlogram of Residuals

k	1	2	3	4	5	6
$\hat{\rho}_k$	0.037 (0.301)	-0.022 (0.179)	0.120 (0.976)	-0.067 (0.545)	-0.308 (2.504)	0.133 (1.081)
k	7	8	9	10	11	12
$\hat{\rho}_k$	0.046 (0.374)	-0.203 (1.650)	-0.039 (0.317)	-0.182 (1.480)	-0.155 (1.260)	-0.321 (2.610)

Note: a. Figures in parentheses are absolute values of the asymptotic t-ratios.

(6.4) is significantly different from zero at the 1 per cent level.<sup>5</sup>

It is also the case that  $\rho_4$  is significantly greater than minus unity and significantly smaller than unity at the 1 per cent level

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5. The test statistic for the test of the null hypothesis  $\rho_4 = 0$  against  $\rho_4 \neq 0$  is of course  $t = \hat{\rho}_4 / \hat{\sigma}_{\hat{\rho}_4}$ , the observed value of which is 3.731 as shown in Table 6.2. Given that the acceptance region for the null hypothesis at the 1 per cent level of significance is  $-2.576 \leq t \leq +2.576$ , rejection of the null hypothesis is indicated.

of significance.<sup>6</sup> The information that  $\rho_4$  is both significantly different from zero and significantly smaller than unity in absolute value at the 1 per cent level is confirmed by the fact, reported in Table 6.2, that the 99 per cent confidence limits for  $\rho_4$  lie entirely within the interval bounded by minus unity and zero. It will be recalled that this condition on  $\rho_4$  is required in the case of the simple fourth-order autoregressive scheme (6.4) to ensure the stationarity of  $V_t$ .<sup>7</sup> It would appear then that the overall performance of the postulated fourth-order autoregressive scheme is quite satisfactory in the present case. It turned out that the correlogram was of the same general form as that reported in Table 6.1 for all estimations except those involving  $y$ . Accordingly the fourth-order scheme was used throughout to correct for autocorrelation, except where  $y$  was involved. The general form of the residuals correlogram for estimations involving  $y$  was similar to that of equation (6.5), reported in Table 6.2, although the ordinate at lag 4, while not significant, was somewhat larger (a typical value was about -0.2 with an approximate asymptotic standard error of 0.137). In these cases, therefore, no autocorrelation correction appeared necessary and none was made.

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6. Testing the null hypothesis  $\rho_4 = -1$  against  $\rho_4 > -1$ , the observed value of the test statistic  $[\hat{\rho}_4 - (-1)]/\hat{\sigma}_{\hat{\rho}_4}$  is 4.597 while the rejection region for the null hypothesis at the 1 per cent level of significance is  $t > 2.326$  indicating acceptance of the alternative hypothesis  $\rho_4 > -1$ . Similarly, testing the null hypothesis  $\rho_4 = +1$  against  $\rho_4 < +1$ , the observed value of  $(\hat{\rho}_4 - 1)/\hat{\sigma}_{\hat{\rho}_4}$  is -12.059 while the rejection region for the null hypothesis at the 1 per cent level is  $t < -2.326$  again indicating acceptance of the alternative hypothesis  $\rho_4 < +1$  at that level of significance.

7. See above, p. 125.

The possibility of using a more complex autoregressive scheme than (6.4) to correct for autocorrelation in the twenty-four cases in which correction appeared necessary,<sup>8</sup> was considered. However, in view of the prohibitive computational cost of doing so, this line was not pursued. A major drawback of iterative estimators like NLLS is that they are very expensive in terms of computer time. A rough comparison is that a single NLLS estimation of the sort undertaken here requires about twenty-five times the computer processing time of an OLS regression with a comparable number of parameters. Another feature of iterative estimators like NLLS which further contributes to the computational cost is the requirement that an initial or starting value be supplied for each of the parameters. As it is the case that the estimator may converge on a local rather than the global minimum of the residual sum of squares function, the estimation is performed using at least two sets of initial values to avoid this possibility whenever there is any question of the converged values not representing a global minimum.

Having disposed of these general matters, the results of the estimations associated with Model A.2 can now be considered. These results are reported in Table 6.3, the first row of which repeats the information given in Table 6.2, while the associated residuals correlograms appear in Table 6.4. As noted above, the sample period for those estimations in which  $f(u_t) = a_0 + a_1 u_t^{-1}$  or  $f(u_t) = a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$  is 1958(3)-1974(4) which consists of 66 observations. For estimations involving EDL I and EDL II the

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8. Excluding estimations involving  $y$ , there are 6 estimates for each of the 4 prototype models.



**TABLE 6.3**  
**NLLS Estimations of Model A.2**

Estimation Number	Variables in $f(u_t)$	Parameter <sup>a</sup>							MSR	99% Confidence Limits for $\rho_4$
		$a_0$	$a_1$	$a_2$	$\alpha$	$\gamma$	$\delta$	$\rho_4^b$		
A.2.1	$u^{-1}$	1.488 (0.569)	1.028 (0.325)		0.368 (1.311)	0.230 <sup>*5</sup> (1.946)	1.599 <sup>*1</sup> (3.858)	-0.448 <sup>*1</sup> (3.731)	2.694	-0.139 -0.757
A.2.2	$u^{-1}, u^{-1}$	1.488 (0.564)	1.029 (0.323)	-0.005 (0.023)	0.369 (1.300)	0.230 <sup>*5</sup> (1.928)	1.598 <sup>*1</sup> (3.825)	-0.447 <sup>*1</sup> (3.658)	2.694	-0.132 -0.762
A.2.3	EDL I	4.379 <sup>*1</sup> (3.907)	1.143 <sup>*10</sup> (1.626)		0.741 (0.643)	0.313 <sup>*1</sup> (2.572)	0.475 (1.144)	-0.436 <sup>*1</sup> (3.398)	2.370	-0.105 -0.767
A.2.4	EDL I, $\Delta$ EDL I	3.075 <sup>*5</sup> (2.100)	0.638 (0.802)	3.729 (1.280)	0.183 (0.423)	0.345 <sup>*1</sup> (2.691)	1.084 <sup>*5</sup> (1.813)	-0.423 <sup>*1</sup> (3.144)	2.285	-0.076 -0.770
A.2.5	EDL II	4.486 <sup>*1</sup> (3.946)	1.236 <sup>*5</sup> (1.694)		0.859 (0.607)	0.308 <sup>*1</sup> (2.551)	0.412 (0.956)	-0.438 <sup>*1</sup> (3.421)	2.358	-0.108 -0.768
A.2.6	EDL II, $\Delta$ EDL II	2.814 <sup>*10</sup> (1.897)	0.577 (0.659)	4.732 <sup>*10</sup> (1.453)	0.109 (0.288)	0.328 <sup>*1</sup> (2.635)	1.202 <sup>*5</sup> (1.837)	-0.446 <sup>*1</sup> (3.397)	2.252	-0.108 -0.784
A.2.7	$y$	-15.645 (0.379)	17.725 (0.435)		0.097 (0.455)	0.207 <sup>*10</sup> (1.572)	1.914 <sup>*1</sup> (2.755)	NC <sup>b</sup>	2.717	
A.2.8	$y, \Delta y$	9.679 (0.237)	-8.264 (0.205)	103.832 <sup>*2.5</sup> (2.073)	0.134 (0.676)	0.212 <sup>*5</sup> (1.672)	2.030 <sup>*1</sup> (1.672)	NC	2.489	
A.2.9	EDL I	4.152 <sup>*1</sup> (3.585)	1.404 <sup>*2.5</sup> (2.128)			0.289 <sup>*1</sup> (2.499)	0.536 (1.238)	-0.435 <sup>*1</sup> (3.353)	2.406	-0.101 -0.769
A.2.10	EDL II	4.277 <sup>*1</sup> (3.577)	1.506 <sup>*2.5</sup> (2.169)			0.280 <sup>*1</sup> (2.461)	0.466 (1.026)	-0.438 <sup>*1</sup> (3.384)	2.394	-0.105 -0.771

**Notes:** a. Figures in parentheses are t-ratios. Superscripts of the form \* $\epsilon$  on an estimate denote that the corresponding parameter is significantly different from zero (where the sign of the parameter is not known *a priori*) or either significantly positive or negative as appropriate (where the sign of the parameter is known *a priori*) at the  $\epsilon$  per cent level of significance. See text, p. 162.

b. All estimations have been corrected for fourth-order autocorrelation except those for which NC (Not Corrected) appears in the  $\rho_4$  column. See text, p. 156.

TABLE 6.4

Residuals Correlograms for NLLS Estimations of Model A.2<sup>a</sup>

Estimation Number	Estimated Autocorrelations $\hat{\psi}_k$ for lag, k =											
	1	2	3	4	5	6	7	8	9	10	11	12
A.2.1	0.037 (0.301)	-0.022 (0.179)	0.120 (0.976)	-0.067 (0.545)	-0.308 (2.504)	0.133 (1.081)	0.046 (0.374)	-0.203 (1.650)	-0.039 (0.317)	-0.182 (1.480)	-0.155 (1.260)	-0.321 (2.610)
A.2.2	0.038 (0.309)	-0.022 (0.179)	0.119 (0.967)	-0.066 (0.537)	-0.308 (2.504)	0.132 (1.073)	0.047 (0.382)	-0.203 (1.650)	-0.039 (0.317)	-0.182 (1.480)	-0.155 (1.260)	-0.321 (2.610)
A.2.3	-0.081 (0.604)	0.018 (0.134)	0.203 (1.515)	-0.035 (0.261)	-0.304 (2.269)	0.231 (1.724)	0.168 (1.254)	-0.094 (0.701)	0.151 (1.127)	-0.068 (0.507)	0.068 (0.507)	-0.229 (1.709)
A.2.4	-0.099 (0.739)	0.009 (0.067)	0.213 (1.590)	-0.022 (0.164)	-0.296 (2.209)	0.244 (1.821)	0.149 (1.112)	-0.113 (0.843)	0.119 (0.888)	-0.074 (0.552)	0.082 (0.612)	-0.239 (1.784)
A.2.5	-0.079 (0.590)	0.021 (0.157)	0.201 (1.500)	-0.037 (0.276)	-0.310 (2.313)	0.235 (1.754)	0.171 (1.276)	-0.097 (0.724)	0.146 (1.090)	-0.064 (0.478)	0.064 (0.478)	-0.228 (1.701)
A.2.6	-0.106 (0.791)	0.018 (0.134)	0.175 (1.306)	-0.025 (0.187)	-0.294 (2.194)	0.238 (1.776)	0.153 (1.142)	-0.117 (0.873)	0.106 (0.791)	-0.101 (0.754)	0.101 (0.754)	-0.223 (1.664)
A.2.7	0.096 (0.698)	-0.023 (0.167)	0.089 (0.645)	-0.207 (1.500)	-0.312 (2.261)	0.169 (1.225)	0.036 (0.261)	-0.123 (0.851)	0.190 (1.377)	-0.139 (1.007)	-0.153 (1.109)	-0.241 (1.746)
A.2.8	0.068 (0.493)	-0.049 (0.355)	0.154 (1.116)	-0.138 (1.000)	-0.279 (2.022)	0.153 (1.145)	-0.013 (0.094)	-0.191 (1.384)	0.091 (0.659)	-0.201 (1.457)	-0.228 (1.652)	-0.244 (1.768)
A.2.9	-0.094 (0.701)	0.051 (0.381)	0.185 (1.381)	-0.032 (0.239)	-0.301 (2.246)	0.176 (1.313)	0.125 (0.933)	-0.123 (0.918)	0.127 (0.948)	-0.113 (0.843)	0.094 (0.701)	-0.208 (1.552)
A.2.10	-0.096 (0.716)	0.053 (0.396)	0.181 (1.351)	-0.034 (0.254)	-0.308 (2.299)	0.181 (1.351)	0.128 (0.955)	-0.127 (0.948)	0.122 (0.910)	-0.105 (0.784)	0.091 (0.679)	-0.206 (1.537)

Note: a. Figures in parentheses are absolute values of the approximate asymptotic t-ratios.

sample period is 1958(3)-1972(1), 55 observations, while for those involving  $y$  the sample period is 1961(4)-1974(4), consisting of 53 observations.

In assessing the significance of the structural coefficients of Model A.2 on the basis of the NLLS estimates which appear in Table 6.3 full use has been made of the information contained in the *a priori* signs of the parameters.<sup>9</sup> It is known *a priori* that  $\gamma$  and  $\delta$  are positive, that  $a_1$  and  $a_2$  are positive and, in those equations for which  $f(u_t) = a_0 + a_1 u_t^{-1}$  or for which  $f(u_t) = a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$ , that  $a_0$  is negative. In each of these cases, a one-tail test of the significance of the parameter is used. For instance, in the test applied to  $\gamma$  the null hypothesis is  $\gamma = 0$  against the alternative  $\gamma > 0$ . The sign of  $\alpha$  and of coefficients like  $\rho_4$  appearing in the autoregressive schemes is not known *a priori*. Also for all cases other than those in which  $f(u_t) = a_0 + a_1 u_t^{-1}$  or  $f(u_t) = a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$ , the sign of  $a_0$  is not known *a priori*. Hence for tests of significance of  $\alpha$ ,  $\rho_4$  and  $a_0$  in the cases just mentioned, a two-tail test of significance is applied.

Estimation A.2.1 in Table 6.3 represents the NLLS estimates (corrected for fourth-order autocorrelation) of the structural parameters of Model A.2 when  $f(u_t) = a_0 + a_1 u_t^{-1}$ . Its overall performance is quite poor. The sign of  $a_0$  is wrong on *a priori* grounds and  $a_1$  is not significantly positive as required even at the 10 per cent level of significance. The estimates of  $\gamma$  and  $\rho_4$  are acceptable in that  $\gamma$  is significantly positive at 5 per cent and  $\rho_4$  is significantly different from zero and smaller than unity in

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9. This applies to the other three models also.

absolute value at the 1 per cent level.<sup>10</sup> While the estimate of  $\delta$  is significantly positive at the 1 per cent level, it is unacceptable since it exceeds unity.

The above remarks apply equally to estimation A.2.2, the NLLS estimates of the structural coefficients of Model A.2 with  $f(u_t) = a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$ . In addition,  $a_2$  has the wrong sign in A.2.2.

The performance of the estimations in which EDL I and EDL II appear is noticeably better than those in which  $f(u_t) = a_0 + a_1 u_t^{-1}$  or  $f(u_t) = a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$ . In each of the four estimations involving EDL I or EDL II (estimations A.2.3, A.2.4, A.2.5 and A.2.6 in Table 6.3) the signs of all parameters are correct on *a priori* grounds and in each case  $a_0$  is significantly different from zero, although rather weakly in estimation A.2.6 (involving the level and change form of EDL II). In all four estimations  $\rho_4$  is significantly non-zero and smaller than unity in absolute value at the 1 per cent level and  $\gamma$  is significantly positive and significantly smaller than unity<sup>11</sup> at that level of significance.  $\alpha$  is not significantly different from zero in any of these four NLLS estimations.<sup>12</sup> The main weakness of these estimations involving EDL I and EDL II is

10. The information in respect of  $\rho_4$  is again conveyed by the 99 per cent confidence limits for  $\rho_4$  shown in Table 6.3.

11. For example, in A.2.5  $\hat{\gamma} = 0.308$  and  $\hat{\sigma}_{\hat{\gamma}} = 0.121$ . Testing  $\gamma = 1$  against  $\gamma < 1$  the observed value of the test statistic  $(\hat{\gamma} - \gamma)/\hat{\sigma}_{\hat{\gamma}}$  is -5.719. The rejection region for the null hypothesis at 1 per cent is  $t < -2.326$  indicating acceptance of the alternative hypothesis  $\gamma < 1$  at this level of significance.

12. It is, of course, important only that at least one of  $\alpha$  and  $\gamma$  be significant.

that in both A.2.3 and A.2.5, where  $f(u_t)$  is replaced by  $a_0 + a_1(\text{EDL I})_t$  and  $a_0 + a_1(\text{EDL II})_t$  respectively,  $\delta$  is not significantly positive. Despite this, these estimations are judged to be preferable to those in which  $f(u_t)$  is replaced by  $a_0 + a_1(\text{EDL I})_t + a_2(\Delta\text{EDL I})_t$  or by  $a_0 + a_1(\text{EDL II})_t + a_2(\Delta\text{EDL II})_t$  - A.2.4 and A.2.6 respectively. The reason for this preference is that in A.2.3 (EDL I appearing) and A.2.5 (EDL II)  $a_1$  is significantly positive, albeit rather weakly in A.2.3. On the other hand, in neither of A.2.4 (EDL I and  $\Delta\text{EDL I}$  appearing) and A.2.6 (EDL II and  $\Delta\text{EDL II}$ ) is either  $a_1$  or  $a_2$  significantly positive at the 5 per cent level. Thus A.2.3 and A.2.5 are clearly preferable to A.2.4 and A.2.6. In view of the weakness of the significance of  $a_1$  in A.2.3, A.2.5 is (marginally) preferred to A.2.3. Each of these is considered superior to A.2.1 and A.2.2.

Turning now to those estimations involving  $y$  (A.2.7 and A.2.8 in Table 6.3),  $a_0$  is not significantly different from zero and  $a_1$  is not significantly positive in either estimation, the point estimate of  $a_1$  in A.2.8 (in terms of the level and change form of  $y$ ) having the wrong sign on *a priori* grounds. Although  $\gamma$  and  $\delta$  are significantly positive the magnitude of the point estimate of  $\delta$  is implausible in both cases in that it exceeds unity. Both A.2.7 and A.2.8 are therefore inferior to A.2.3 and A.2.5.

Although there is little doubt that A.2.3 and A.2.5 are superior to all the other NLLS estimations of Model A.2 reported in Table 6.3, the choice between them is not an obvious one, A.2.5 being tentatively preferred on the basis of  $a_1$  being more strongly significantly positive there than in A.2.3. Having regard to this and the fact that  $\alpha$  is insignificantly different from zero in both

A.2.3 and A.2.5, it seems appropriate to re-estimate both equations with  $\alpha$  constrained to zero<sup>13</sup> and to make the comparison between them again. These re-estimations of A.2.3 and A.2.5 are respectively A.2.9 and A.2.10 in Table 6.3. The effect of the modification is to make the comparison more difficult still.<sup>14</sup> A.2.9 and A.2.10 are therefore selected as "equally preferred" estimations of Model A.2. A.2.9 and A.2.10 are selected in preference to their respective parent estimations A.2.3 and A.2.5 because  $\alpha$  was not significantly different from zero in either A.2.3 and A.2.5 while all parameters are significantly positive or non-zero as appropriate in A.2.9 and A.2.10. Furthermore, while some of the t-ratios in A.2.9 are marginally smaller than the corresponding one in A.2.3, the t-ratios on the crucial parameters  $a_1$  and  $\delta$  are noticeably larger. The goodness of fit (measured by MSR) of A.2.9 is not noticeably different from that of A.2.3 and there is nothing to choose between them on that basis. Precisely the same remarks apply to the comparison between A.2.10 and A.2.5.

The equally preferred estimated forms of Model A.2 are therefore<sup>15</sup>

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13. The effect of constraining  $\alpha$  to zero is to replace the mixed expectations adjustment scheme with straight adaptive expectations. See above, p. 111.
  14. The strong similarity between the results obtained using EDL I and II is not surprising in view of the fact that EDL II is constructed from EDL I. See above, p. 136.
  15. The  $e_{it}$ ,  $i = 1, 2, 3, 4$ , denote the NLLS residuals. The coefficient of  $p_{t-1}^e$  is  $(1 - \hat{\gamma})$  where  $\hat{\gamma}$  denotes the estimate of  $\gamma$ . See (6.2) above. The associated t-ratio is calculated using  $\text{var}(1 - \hat{\gamma}) = \text{var}(\hat{\gamma})$ .

## A.2.9

$$w_t = \frac{4.152}{(3.585)} + \frac{1.404}{(2.128)} (\text{EDL I})_t + \frac{0.536p_t^e}{(1.238)} + e_{1t} \quad (6.6)$$

$$p_t^e = \frac{0.289p_{t-1}}{(2.499)} + \frac{0.711p_{t-1}^e}{(6.148)} + e_{2t} \quad (6.7)$$

## A.2.10

$$w_t = \frac{4.277}{(3.577)} + \frac{1.506}{(2.169)} (\text{EDL II})_t + \frac{0.466p_t^e}{(1.026)} + e_{3t} \quad (6.8)$$

$$p_t^e = \frac{0.280p_{t-1}}{(2.461)} + \frac{0.720p_{t-1}^e}{(6.328)} + e_{4t} \quad (6.9)$$

6.3 Estimates of the Structural Ccoefficients of Model A.1

The structural form of Model A.1, with  $f(u_t) = a_0 + a_1 u_t^{-1}$  is as follows.

$$w_t = a_0 + a_1 u_t^{-1} + p_t^e + \varepsilon_{1t} \quad (6.10)$$

$$p_t^e = (\alpha + \gamma)p_{t-1} - \alpha p_{t-2} + (1 - \gamma)p_{t-1}^e + \varepsilon_{2t} \quad (6.11)$$

The equation for  $w_t$  in the reduced form of this system is

$$w_t = a_0 \gamma + a_1 u_t^{-1} - a_1 (1 - \gamma) u_{t-1}^{-1} + (\alpha + \gamma) p_{t-1} - p_{t-2} + (1 - \gamma) w_{t-1} + v_t \quad (6.12)$$

As before<sup>16</sup> the structural and reduced form equations for  $w_t$  in terms of the other labour excess demand proxies can be obtained by appropriately modifying (6.10) and (6.12).

The NLLS estimates of the structural coefficients of Model A.1 corresponding to the eight forms of  $f(u_t)$  are reported in Table 6.5. The associated residuals correlograms appear in Table 6.6.

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16. See above, p. 154n.

TABLE 6.5  
NLLS Estimations of Model A.1<sup>a</sup>

Estimation Number	Variables in $f(u_t)$	Parameter						MSR	99% Confidence Limits for $\rho_4$
		$a_0$	$a_1$	$a_2$	$\alpha$	$\gamma$	$\rho_4$		
A.1.1	$u^{-1}$	4.786 (2.131)	-1.165 (0.369)		1.040 <sup>*1</sup> (3.978)	0.216 <sup>*5</sup> (1.876)	-0.466 <sup>*1</sup> (3.975)	2.860	-0.164 -0.768
A.1.2	$u^{-1}, \dot{u}^{-1}$	3.730 (2.105)	0.116 (0.045)	-1.064 (2.329)	1.068 <sup>*1</sup> (4.220)	0.322 <sup>*1</sup> (2.927)	-0.485 <sup>*1</sup> (4.379)	2.654	-0.200 -0.770
A.1.3	EDL I	3.218 <sup>*1</sup> (4.521)	0.895 (1.228)		0.224 (0.560)	0.270 <sup>*5</sup> (2.291)	-0.450 <sup>*1</sup> (3.536)	2.442	-0.122 -0.778
A.1.4	EDL I, $\Delta$ EDL I	3.590 <sup>*1</sup> (5.213)	0.258 (0.383)	2.852 (1.116)	0.232 (0.570)	0.271 <sup>*2.5</sup> (2.108)	-0.481 <sup>*1</sup> (3.515)	2.450	-0.128 -0.834
A.1.5	EDL II	3.207 <sup>*1</sup> (4.363)	0.926 (1.230)		0.219 (0.551)	0.260 <sup>*2.5</sup> (2.229)	-0.452 <sup>*1</sup> (3.551)	2.441	-0.124 -0.780
A.1.6	EDL II, $\Delta$ EDL II	3.532 <sup>*1</sup> (5.915)	-0.280 (0.440)	2.333 (0.879)	0.411 (0.823)	0.387 <sup>*1</sup> (2.517)	-0.472 <sup>*1</sup> (2.805)	3.606	-0.039 -0.905
A.1.7	$y$	27.672 (0.735)	-22.439 (0.598)		0.712 <sup>*2.5</sup> (2.377)	0.213 <sup>*5</sup> (1.669)	NC	2.979	
A.1.8	$y, \Delta y$	58.579 (1.442)	-52.849 (1.298)	92.270 <sup>*5</sup> (1.772)	0.827 <sup>*1</sup> (2.744)	0.139 (1.199)	NC	2.810	
A.1.9	EDL I	3.139 <sup>*1</sup> (4.275)	1.137 <sup>*5</sup> (1.784)			0.253 <sup>*2.5</sup> (2.272)	-0.448 <sup>*1</sup> (3.533)	2.457	-0.121 -0.775
A.1.10	EDL II	3.125 <sup>*1</sup> (4.063)	1.182 <sup>*5</sup> (1.774)			0.240 <sup>*2.5</sup> (2.190)	-0.451 <sup>*1</sup> (3.557)	2.455	-0.124 -0.778

Note: a. Notes as in Table 6.3.



TABLE 6.6

Residuals Correlograms for NLLS Estimations of Model A.1<sup>a</sup>

Estimation Number	Estimated Autocorrelations $\hat{\psi}_k$ for lag, k =											
	1	2	3	4	5	6	7	8	9	10	11	12
A.1.1	0.043 (0.350)	-0.069 (0.561)	0.100 (0.813)	-0.073 (0.593)	-0.279 (2.268)	0.221 (1.797)	0.141 (1.146)	-0.118 (0.959)	0.013 (0.106)	-0.116 (0.943)	-0.115 (0.935)	-0.260 (2.114)
A.1.2	0.061 (0.496)	-0.057 (0.463)	0.089 (0.724)	-0.105 (0.854)	-0.218 (1.772)	0.221 (1.797)	0.090 (0.732)	-0.115 (0.935)	0.052 (0.423)	-0.169 (1.374)	-0.054 (0.439)	-0.164 (1.333)
A.1.3	-0.103 (0.769)	0.014 (0.104)	0.177 (1.321)	-0.047 (0.351)	-0.339 (2.530)	0.167 (1.246)	0.100 (0.746)	-0.157 (1.172)	0.079 (0.590)	-0.127 (0.948)	0.032 (0.239)	-0.280 (2.090)
A.1.4	-0.083 (0.619)	0.039 (0.291)	0.163 (1.216)	-0.046 (0.343)	-0.343 (2.560)	0.157 (1.172)	0.132 (0.985)	-0.079 (0.590)	0.166 (1.239)	-0.036 (0.269)	0.083 (0.619)	-0.273 (2.037)
A.1.5	-0.105 (0.784)	0.015 (0.112)	0.174 (1.299)	-0.049 (0.366)	-0.346 (2.582)	0.166 (1.239)	0.098 (0.731)	-0.162 (1.209)	0.072 (0.537)	-0.125 (0.933)	0.028 (0.209)	-0.282 (2.104)
A.1.6	-0.144 (1.075)	-0.207 (1.545)	0.207 (1.545)	-0.116 (0.866)	-0.222 (1.657)	0.170 (1.269)	0.106 (0.791)	-0.158 (1.179)	0.213 (1.590)	0.015 (0.112)	-0.007 (0.052)	-0.142 (1.060)
A.1.7	0.136 (1.015)	-0.046 (0.343)	0.081 (0.604)	-0.222 (1.657)	-0.294 (2.194)	0.242 (1.806)	0.111 (0.828)	-0.059 (0.440)	0.178 (1.328)	-0.136 (1.015)	-0.154 (1.149)	-0.203 (1.515)
A.1.8	0.079 (0.590)	-0.079 (0.590)	0.156 (1.164)	-0.160 (1.194)	-0.285 (2.127)	0.249 (1.858)	0.076 (0.567)	-0.120 (0.896)	0.134 (1.000)	-0.170 (1.269)	-0.205 (1.530)	-0.207 (1.545)
A.1.9	-0.116 (0.866)	0.034 (0.254)	0.167 (1.246)	-0.044 (0.328)	-0.333 (2.485)	0.141 (1.052)	0.083 (0.619)	-0.166 (1.239)	0.077 (0.575)	-0.148 (1.104)	0.058 (0.433)	-0.256 (1.910)
A.1.10	-0.121 (0.903)	0.034 (0.254)	0.162 (1.209)	-0.047 (0.351)	-0.341 (2.545)	0.143 (1.067)	0.083 (0.619)	-0.173 (1.291)	0.069 (0.515)	-0.144 (1.075)	0.054 (0.403)	-0.258 (1.925)

Note: a. Figures in parentheses are absolute values of the approximate asymptotic t-ratios.

The sample periods are the same as those used in the estimation of Model A.2.<sup>17</sup>

The first two estimations reported in Table 6.5, namely A.1.1 and A.1.2, are the NLLS estimates of the structural coefficients of Model A.1 when  $f(u_t)$  is replaced by  $a_0 + a_1 u_t^{-1}$  and  $a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$  respectively. The signs of both  $a_0$  and  $a_1$  in A.1.1 are incorrect on *a priori* grounds. In A.1.2,  $a_0$  and  $a_2$  have the wrong *a priori* signs and  $a_1$ , although correctly signed, has a very low t-ratio indeed and is not significantly positive. The estimations involving  $y$  (A.1.7 and A.1.8) are similarly poor. In both A.1.7 and A.1.8,  $a_1$  has the wrong sign and  $a_0$  is not significantly different from zero.

The estimations in which EDL I or EDL II appears are a little better. In A.1.3, A.1.4 and A.1.5 all the point estimates are correctly signed. In A.1.6  $a_1$  has the wrong sign on the basis of *a priori* considerations but all other parameters are correctly signed. In none of these four estimations is  $a_1$  significantly positive. A.1.4 performs a little worse than A.1.3 in that  $a_0$  is not significant in A.1.4 but is significant at 1 per cent in A.1.3. In addition, A.1.3 is marginally superior to A.1.4 in terms of goodness of fit. Similarly, A.1.5 is preferable to A.1.6. A.1.5 has a markedly smaller mean square residual and, as noted above,  $a_1$  is incorrectly signed in A.1.6.

In both A.1.3 and A.1.5  $\gamma$  is significantly positive, at the 5 per cent level in A.1.3 and at the 2.5 per cent level in A.1.5, and is significantly smaller than unity at the 1 per cent level.<sup>18</sup> The parameter  $\rho_4$  is significantly different from zero

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17. See above, p. 159.

18. In A.1.3, for example,  $(\hat{\gamma} - 1)/\hat{\sigma}_{\hat{\gamma}} = -6.194$ .

and smaller than unity in absolute value at the 1 per cent level in each case. On the other hand, in neither estimation is  $\alpha$  significantly different from zero.

It is fairly clear then that A.1.3 and A.1.4 are superior to all the other estimations of Model A.1 which have been discussed so far. The question then arises as to whether it is possible to distinguish between them. In view of their marked similarity and the fact that  $\alpha$  is insignificant in both, it is again appropriate to re-estimate A.1.3 and A.1.5 with  $\alpha$  constrained to zero<sup>19</sup> before attempting to select one of them as preferable. These re-estimations of A.1.3 and A.1.5 are reported in Table 6.5 as A.1.9 and A.1.10 respectively.

It can be noted immediately that both A.1.9 and A.1.10 are superior to their parent estimations (A.1.3 and A.1.5 respectively) in that all the desirable features have carried over to the re-estimations and, in addition, the parameter  $a_1$  which was not significantly positive in A.1.3 or A.1.5 is significantly positive at the 5 per cent level in A.1.9 and A.1.10. Although in each case the re-estimation has produced an increase in the mean square residual, the increase is very slight.

It is, however, impossible to distinguish between A.1.9 and A.1.10, their performance (as was expected) being very similar indeed. Accordingly, A.1.9 and A.1.10 are selected as the equally preferred estimations of Model A.1. These estimated forms of Model A.1 are<sup>20</sup>

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19. As was noted above, the effect of constraining  $\alpha$  to zero is to replace the mixed expectations scheme with the adaptive expectations scheme.

20.  $e_{it}$  again denotes the NLLS residual.

## A.1.9

$$w_t = \frac{3.139}{(4.275)} + \frac{1.137(\text{EDL I})}{(1.784)}_t + p_t^e + e_{1t} \quad (6.13)$$

$$p_t^e = \frac{0.253p}{(2.272)}_{t-1} + \frac{0.747p^e}{(6.708)}_{t-1} + e_{2t} \quad (6.14)$$

## A.1.10

$$w_t = \frac{3.125}{(4.063)} + \frac{1.182(\text{EDL II})}{(1.774)}_t + p_t^e + e_{3t} \quad (6.15)$$

$$p_t^e = \frac{0.240p}{(2.190)}_{t-1} + \frac{0.760p^e}{(6.935)}_{t-1} + e_{4t} \quad (6.16)$$

6.4 Estimates of the Structural Coefficients of Model B.2

The structural form of Model B.2 with  $f(u_t) = a_0 + a_1 u_t^{-1}$  is as follows.

$$w_t = a_0 + a_1 u_t^{-1} + \delta w_t^e + \epsilon_{1t} \quad (6.17)$$

$$w_t^e = (\alpha + \gamma)w_{t-1} - \alpha w_{t-2} + (1 - \gamma)w_{t-1}^e + \epsilon_{2t} \quad (6.18)$$

The equation for  $w_t$  in the reduced form of this system is

$$w_t = a_0 \gamma + a_1 u_t^{-1} - a_1 (1 - \gamma) u_{t-1}^{-1} + [1 - \gamma + (\alpha + \gamma)\delta]w_{t-1} - \alpha \delta w_{t-2} + v_t \quad (6.19)$$

The structural and reduced form equations for  $w_t$  in terms of the other proxies for the excess demand for labour can again be obtained by appropriately modifying (6.17) and (6.19).<sup>21</sup> The NLLS estimates of

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21. See above, p. 154n.

Model B.2 appear in Table 6.7 while the associated residuals correlograms appear in Table 6.8. The sample periods are the same as those used in previous estimations.<sup>22</sup>

The general quality of the results of the NLLS estimations is quite poor. Aside from the autoregressive parameter  $\rho_4$  which is significantly different from zero and smaller than unity in absolute value at the 1 per cent level in all corrected equations, in only two cases is the parameter in question significant, namely the parameter  $a_1$  in B.2.3 and B.2.5, the versions of Model B.2 in terms of EDL I and EDL II respectively. Estimations B.2.1 and B.2.2, which involve  $u^{-1}$ , can be rejected immediately because some of the point estimates of the parameters are incorrectly signed on *a priori* grounds. This is true of  $a_0$  and  $\gamma$  in B.2.1 and of  $a_1$  and  $a_2$  in B.2.2. Furthermore in B.2.2 the point estimates of both  $\gamma$  and  $\delta$  are unacceptable in that they are implausibly greater than unity. The estimations in which  $y$  appears (B.2.7 and B.2.8) can similarly be rejected outright because in both cases the point estimate of  $\gamma$  is negative. In addition, B.2.8 suffers from the further defect that the point estimate of  $\delta$  has the wrong *a priori* sign.

The signs of all the parameters are correct on *a priori* grounds in those estimations involving EDL I and EDL II. The level only forms of EDL I and EDL II appear in B.2.3 and B.2.5 respectively while their level and change forms appear respectively in B.2.4 and B.2.6. The level only form is superior in each case because, as was noted earlier, in these estimations  $a_1$  is significantly positive at the 5 per cent level (but no other structural parameter is significant)

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22. See above, p. 159.

TABLE 6.7

NLLS Estimations of Model B.2<sup>a</sup>

Estimation Number	Variables in $f(u_t)$	Parameter							MSR	99% Confidence Limits for $\rho_4$
		$a_0$	$a_1$	$a_2$	$\alpha$	$\gamma$	$\delta$	$\rho_4$		
B.2.1	$u^{-1}$	0.306 (0.114)	4.903 (1.166)		-0.553 (0.397)	-0.301 (0.890)	0.346 (0.448)	-0.414 <sup>*1</sup> (3.437)	3.101	-0.104 -0.724
B.2.2	$u^{-1}, \dot{u}^{-1}$	-0.030 (0.089)	-0.463 (0.769)	-0.287 (0.986)	-0.146 (1.025)	2.261 (1.286)	1.066 (19.017)	-0.372 <sup>*1</sup> (2.967)	3.027	-0.049 -0.695
B.2.3	EDL I	3.661 (1.136)	1.600 <sup>*5</sup> (1.795)		-0.793 (0.578)	0.214 (0.937)	0.322 (0.624)	-0.509 <sup>*1</sup> (4.078)	2.330	-0.187 -0.831
B.2.4	EDL I, $\Delta$ EDL I	1.582 (0.318)	0.829 (0.288)	2.148 (0.961)	-0.380 (0.696)	0.425 (0.346)	0.699 (0.715)	-0.504 <sup>*1</sup> (3.823)	2.288	-0.164 -0.844
B.2.5	EDL II	4.097 (1.153)	1.742 <sup>*5</sup> (1.919)		-1.018 (0.415)	0.195 (1.002)	0.243 (0.430)	-0.512 <sup>*1</sup> (4.111)	2.317	-0.191 -0.833
B.2.6	EDL II, $\Delta$ EDL II	2.065 (0.019)	1.138 (0.019)	2.723 (0.044)	-0.463 (0.029)	0.291 (0.019)	0.606 (0.029)	-0.518 <sup>*1</sup> (4.150)	2.257	-0.196 -0.840
B.2.7	y	-12.641 (0.337)	13.660 (0.336)		-0.185 (0.670)	-0.848 (0.298)	0.791 (1.120)	NC	3.078	
B.2.8	y, $\Delta y$	-7.954 (0.081)	13.415 (0.193)	74.454 (0.793)	0.545 (0.017)	-0.144 (0.151)	-0.128 (0.018)	NC	2.968	

Note: a. Notes as in Table 6.3.

TABLE 6.8

Residuals Correlograms for NLLS Estimations of Model B.2<sup>a</sup>

Estimation Number	Estimated Autocorrelations $\hat{\psi}_k$ for lag, k =											
	1	2	3	4	5	6	7	8	9	10	11	12
B.2.1	-0.037 (0.301)	-0.064 (0.520)	0.136 (1.106)	-0.064 (0.520)	-0.328 (2.667)	0.088 (0.715)	0.066 (0.537)	-0.214 (1.740)	0.029 (0.236)	-0.085 (0.691)	-0.030 (0.244)	-0.195 (1.585)
B.2.2	-0.011 (0.089)	-0.017 (0.138)	0.128 (1.041)	-0.058 (0.472)	-0.278 (2.260)	0.067 (0.545)	-0.001 (0.008)	-0.194 (1.577)	0.022 (0.179)	-0.099 (0.805)	-0.005 (0.041)	-0.142 (1.154)
B.2.3	-0.027 (0.200)	-0.092 (0.681)	0.158 (1.170)	-0.068 (0.504)	-0.374 (2.770)	0.170 (1.259)	0.195 (1.444)	-0.144 (1.067)	0.056 (0.415)	-0.055 (0.407)	0.068 (0.504)	-0.176 (1.304)
B.2.4	-0.060 (0.444)	-0.121 (0.896)	0.171 (1.267)	-0.066 (0.489)	-0.388 (2.874)	0.194 (1.437)	0.208 (1.541)	-0.152 (1.126)	0.048 (0.356)	-0.043 (0.319)	0.068 (0.504)	-0.187 (1.385)
B.2.5	-0.023 (0.170)	-0.083 (0.615)	0.155 (1.148)	-0.068 (0.504)	-0.374 (2.770)	0.177 (1.311)	0.199 (1.474)	-0.145 (1.074)	0.049 (0.363)	-0.048 (0.356)	0.067 (0.496)	-0.175 (1.296)
B.2.6	-0.053 (0.430)	-0.130 (0.963)	0.156 (1.156)	-0.070 (0.519)	-0.389 (2.881)	0.204 (1.511)	0.226 (1.674)	-0.152 (1.126)	0.034 (0.252)	-0.048 (0.356)	0.073 (0.541)	-0.176 (1.304)
B.2.7	-0.004 (0.029)	-0.040 (0.292)	0.159 (1.161)	-0.184 (1.343)	-0.323 (2.358)	0.167 (1.219)	0.004 (0.029)	-0.223 (1.628)	0.183 (1.336)	-0.085 (0.620)	-0.053 (0.387)	-0.139 (1.015)
B.2.8	-0.042 (0.307)	-0.029 (0.212)	0.225 (1.642)	-0.096 (0.701)	-0.281 (2.051)	0.175 (1.277)	-0.041 (0.299)	-0.285 (2.080)	0.136 (0.993)	-0.155 (1.131)	-0.089 (0.650)	-0.128 (0.934)

Note: a. Figures in parentheses are absolute values of the approximate asymptotic t-ratios.

while none of the structural parameters is significant in those estimations involving the level and change form of EDL I or EDL II.

While estimations B.2.3 and B.2.5 are preferable to all the other NLLS estimations of Model B.2, they are still quite poor. Perhaps their most serious defect is that neither of the parameters  $\alpha$  and  $\gamma$  of the mixed expectations adjustment scheme is significant.<sup>23</sup>

There is again little to choose between B.2.3 and B.2.5, the quality of the NLLS estimates being quite similar both in terms of significance of individual parameters and overall goodness of fit. It is appropriate therefore to select this pair of estimations as the equally preferred estimations of Model B.2. Furthermore, there is no clear avenue for improvement of these preferred equations (as was the case with Models A.1 and A.2) along the lines of modifying the expectations adjustment scheme because *both* parameters of the mixed expectations scheme (viz.  $\alpha$  and  $\gamma$ ) are insignificant.<sup>24</sup>

The preferred estimated forms of Model B.2 are therefore<sup>25</sup>

23. When both  $\alpha$  and  $\gamma$  are zero, the mixed expectations scheme (6.18) reduces to  $w_t^e = w_{t-1}^e$ , the case of constant expectations. This scheme, apart from being implausible, can not be considered from the point of view of estimation because the reduced form equation for  $w_t$  includes the unobservable variable  $w_{t-1}^e$ .

24. See above, this page.

25. As before, the  $e_{it}$  denote the NLLS residuals. The coefficient of  $w_{t-1}$  is  $(\hat{\alpha} + \hat{\gamma})$  where  $\hat{\alpha}$  and  $\hat{\gamma}$  denote the estimates of  $\alpha$  and  $\gamma$  respectively. See (6.18) above. The associated t-ratio is calculated using  $\text{var}(\hat{\alpha} + \hat{\gamma}) = \text{var}(\hat{\alpha}) + \text{var}(\hat{\gamma}) + 2 \text{cov}(\hat{\alpha}, \hat{\gamma})$ . The covariance,  $\text{cov}(\hat{\alpha}, \hat{\gamma})$  is 0.2123 for B.2.3 and 0.3334 in the case of B.2.5.



## B.2.3

$$w_t = \frac{3.661}{(1.136)} + \frac{1.600(\text{EDL I})}{(1.795)}_t + \frac{0.322w_t^e}{(0.624)} + e_{1t} \quad (6.20)$$

$$w_t^e = \frac{-0.579w_{t-1}}{(0.378)} + \frac{0.793w_{t-2}}{(0.578)} + \frac{0.786w_{t-1}^e}{(3.621)} + e_{2t} \quad (6.21)$$

## B.2.5

$$w_t = \frac{4.097}{(1.153)} + \frac{1.742(\text{EDL II})}{(1.919)}_t + \frac{0.243w_t^e}{(0.430)} + e_{3t} \quad (6.22)$$

$$w_t^e = \frac{-0.823w_{t-1}}{(0.317)} + \frac{1.018w_{t-2}}{(0.415)} + \frac{0.805w_{t-1}^e}{(4.135)} + e_{4t} \quad (6.23)$$

6.5 Estimates of the Structural Coefficients of Model B.1

The final prototype model to be considered is Model B.1.

Its structural form when  $f(u_t) = a_0 + a_1 u_t^{-1}$  is as follows.

$$w_t = a_0 + a_1 u_t^{-1} + w_t^e + e_{1t} \quad (6.24)$$

$$w_t^e = (\alpha + \gamma)w_{t-1} - \alpha w_{t-2} + (1 - \gamma)w_{t-1}^e + e_{2t} \quad (6.25)$$

The corresponding reduced form equation for  $w_t$  is

$$w_t = a_0 \gamma + a_1 u_t^{-1} - a_1 (1 - \gamma) u_{t-1}^{-1} + (1 + \alpha)w_{t-1} - \alpha w_{t-2} + v_t \quad (6.26)$$

As usual the structural and reduced form equations for  $w_t$  in terms of the other excess demand for labour proxies can be obtained by making the appropriate modifications to (6.24) and (6.26).<sup>26</sup> The NLLS

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26. See above, p. 154n.

estimates of the various forms of Model B.2 appear in Table 6.9 while the associated residuals correlograms are reported in Table 6.10. The sample periods are again identical to those used in earlier estimations.<sup>27</sup>

The general quality of those estimations in which  $u^{-1}$  or  $y$  appears are very poor. Aside from the parameter  $\rho_4$  of the autoregressive scheme which is significant whenever it appears,<sup>28</sup> no parameter is significant on the basis of the appropriate test even at the 10 per cent level of significance. In addition the sign or magnitude of at least one parameter is incorrect on *a priori* grounds in each of these four estimations. The point estimate of  $\gamma$  is negative and implausibly large in B.1.1 for which  $f(u_t) = a_0 + a_1 u_{t-1}^{-1}$ . In B.1.2,  $f(u_t) = a_0 + a_1 u_t^{-1} + a_2 \dot{u}_t^{-1}$  and here both  $a_1$  and  $a_2$  are incorrectly signed on *a priori* grounds while, in addition, the point estimate of  $\gamma$  exceeds unity. The level only form of  $y$  and its level and change form replace  $f(u_t)$  in B.1.7 and B.1.8 respectively. In each of these estimations,  $a_1$  estimates negatively which is incorrect *a priori*. Further, in B.1.7 the point estimate of  $\gamma$  exceeds unity while in B.1.8 it is negative, both of which are ruled out on *a priori* grounds. Accordingly, all four estimations, B.1.1 and B.1.2 in terms of  $u^{-1}$  and B.1.7 and B.1.8 in terms of  $y$ , are discarded as being quite unsatisfactory.

The level only forms of EDL I and EDL II appear in B.1.3 and B.1.5 respectively. As was the case with the previous prototype models discussed, the results of these two estimations are very similar

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27. See above, p. 159.

28.  $\rho_4$  is also significantly smaller than unity in absolute value in all corrected estimations.

TABLE 6.9  
NLLS Estimations of Model B.1<sup>a</sup>

Estimation Number	Variables in $f(u_t)$	Parameter						MSR	99% Confidence Limits for $\rho_4$
		$a_0$	$a_1$	$a_2$	$\alpha$	$\gamma$	$\rho_4$		
B.1.1	$u^{-1}$	-0.149 (0.025)	0.105 (0.025)		0.096 (0.724)	-3.477 (0.024)	-0.297 <sup>*1</sup> (2.204)	3.521	0.050 -0.644
B.1.2	$u^{-1}, \dot{u}^{-1}$	0.190 (0.465)	-0.094 (0.163)	-0.380 (1.257)	0.053 (0.406)	2.023 (1.609)	-0.287 <sup>*5</sup> (2.123)	3.304	0.061 -0.635
B.1.3	EDL I	1.857 (0.198)	1.672 <sup>*5</sup> (1.892)		-0.357 <sup>*1</sup> (2.639)	0.038 (0.331)	-0.548 <sup>*1</sup> (4.704)	2.403	-0.248 -0.848
B.1.4	EDL I, $\Delta$ EDL I	0.050 (0.114)	0.331 (0.397)	3.097 <sup>*10</sup> (1.616)	-0.348 <sup>*1</sup> (2.585)	0.433 (0.830)	-0.536 <sup>*1</sup> (4.353)	2.349	-0.219 -0.853
B.1.5	EDL II	2.662 (0.179)	1.760 <sup>*5</sup> (1.957)		-0.349 <sup>*1</sup> (2.611)	0.029 (0.265)	-0.551 <sup>*1</sup> (4.759)	2.393	-0.253 -0.849
B.1.6	EDL II, $\Delta$ EDL II	-0.030 (0.030)	0.958 (0.029)	3.788 (0.112)	-0.355 <sup>*1</sup> (2.669)	0.194 (0.029)	-0.547 <sup>*1</sup> (4.573)	2.308	-0.239 -0.855
B.1.7	$y$	4.800 (0.108)	-4.347 (0.107)		0.074 (0.502)	1.002 (0.106)	NC	3.401	
B.1.8	$y, \Delta y$	11.806 (0.008)	-13.459 (0.008)	64.058 (0.040)	0.117 (0.773)	-0.251 (0.008)	NC	3.249	

Note: a. Notes as in Table 6.3.

TABLE 6.10

Residuals Correlograms for NLLS Estimations of Model B.1<sup>a</sup>

Estimation Number	Estimated Autocorrelations $\hat{\psi}_k$ for lag, k =											
	1	2	3	4	5	6	7	8	9	10	11	12
B.1.1	-0.015 (0.122)	0.095 (0.772)	0.200 (1.626)	-0.031 (0.252)	-0.186 (1.512)	0.127 (1.033)	0.023 (0.187)	-0.126 (1.024)	0.071 (0.577)	-0.119 (0.967)	0.027 (0.220)	-0.115 (0.935)
B.1.2	-0.021 (0.171)	0.055 (0.447)	0.161 (1.309)	-0.023 (0.187)	-0.150 (1.220)	0.123 (1.000)	0.001 (0.008)	-0.121 (0.984)	0.068 (0.553)	-0.103 (0.837)	0.048 (0.390)	-0.081 (0.659)
B.1.3	-0.069 (0.511)	-0.197 (1.459)	0.126 (0.933)	-0.091 (0.674)	-0.427 (3.163)	0.171 (1.267)	0.224 (1.659)	-0.173 (1.281)	0.012 (0.089)	-0.041 (0.304)	0.060 (0.444)	-0.193 (1.430)
B.1.4	-0.111 (0.822)	-0.219 (1.622)	0.147 (1.089)	-0.085 (0.630)	-0.444 (3.289)	0.196 (1.452)	0.234 (1.733)	-0.184 (1.363)	0.003 (0.022)	-0.024 (0.178)	0.058 (0.430)	-0.212 (1.570)
B.1.5	-0.066 (0.489)	-0.189 (1.400)	0.122 (0.904)	-0.092 (0.681)	-0.428 (3.170)	0.177 (1.311)	0.228 (1.689)	-0.175 (1.296)	0.001 (0.007)	-0.034 (0.252)	0.059 (0.437)	-0.191 (1.415)
B.1.6	-0.109 (0.807)	-0.223 (1.652)	0.129 (0.956)	-0.090 (0.667)	-0.441 (3.267)	0.203 (1.504)	0.250 (1.852)	-0.181 (1.341)	-0.011 (0.081)	-0.041 (0.304)	0.065 (0.481)	-0.199 (1.474)
B.1.7	-0.006 (0.044)	0.069 (0.504)	0.252 (1.839)	-0.075 (0.547)	-0.214 (1.562)	0.204 (1.489)	-0.001 (0.007)	-0.231 (1.686)	0.191 (1.394)	-0.134 (0.978)	-0.048 (0.350)	-0.079 (0.577)
B.1.8	-0.015 (0.109)	0.076 (0.555)	0.290 (2.117)	-0.032 (0.234)	-0.228 (1.664)	0.188 (1.372)	-0.054 (0.394)	-0.291 (2.124)	0.163 (1.190)	-0.200 (1.460)	-0.090 (0.657)	-0.095 (0.693)

Note: a. Figures in parentheses are absolute values of the approximate asymptotic t-ratios.

indeed. All parameters are correctly signed on *a priori* grounds. In each case,  $a_1$  is significantly positive at the 5 per cent level and  $\alpha$  is significantly different from zero at the 1 per cent level. The autoregressive parameter  $\rho_4$  is significantly different from zero and smaller than unity in absolute value at 1 per cent in both. On the other hand,  $a_0$  is insignificant and  $\gamma$  is not significantly positive in either estimation. There is also very little difference in the goodness of fit of B.1.3 and B.1.5 as reflected by the mean square residual.

The level and change forms of EDL I and EDL II appear in the estimations reported in Table 6.9 as B.1.4 and B.1.6 respectively. In neither of these estimations is  $a_1$  significantly positive. In B.1.4  $a_2$  is significantly positive but only at the 10 per cent level while in B.1.6 it is insignificant. As was the case with B.1.3 and B.1.5,  $\alpha$  and  $\rho_4$  are again significantly different from zero at the 1 per cent level,  $\rho_4$  also being significantly smaller than unity in absolute value at that level, and  $\gamma$  is not significantly positive.

It is clear that, among the NLLS estimations of Model B.1, B.1.3 and B.1.5 are ranked equal first, B.1.4 and B.1.6 are ranked equally next and the remaining estimations follow. B.1.3 and B.1.5 are therefore selected as the equally preferred estimations of Model B.1.

As in the case of Models A.1 and A.2, re-estimation after modifying the form of the expectations adjustment scheme was considered at this stage. In both the preferred estimations B.1.3 and B.1.5,  $\gamma$  is not significantly positive while  $\alpha$  is significantly different from zero. Accordingly it might seem appropriate to re-estimate B.1.3 and B.1.5 while constraining  $\gamma$  to zero. The effect

on the model of imposing this constraint is to replace the mixed expectations scheme (6.25) with the process identified by Valentine [135, p. 3] (See also above, p. 111) in which the change in  $w^e$  is proportional to the change in  $w_t$ ,  $w_{t-1} - w_{t-2}$ . Unfortunately re-estimation of B.1.3 and B.1.5 along these lines is not possible because the reduced form equation for  $w_t$  becomes

$$w_t = a_1 EDL_t - a_1 EDL_{t-1} + (1 + \alpha\delta)w_{t-1} - \alpha\delta w_{t-2} + v_t$$

As this reduced form equation does not contain  $a_0$ , estimation of that parameter is not possible using the RF approach. Accordingly this line was not adopted, B.1.3 and B.1.5 being retained without modification as the preferred estimations of Model B.1.

The estimated forms of Model B.1 are therefore<sup>29</sup>

### B.1.3

$$w_t = \frac{1.857}{(0.198)} + \frac{1.672(EDL I)}{(1.892)}_t + w_t^e + e_{1t} \quad (6.27)$$

$$w_t^e = \frac{-0.319w}{(1.813)}_{t-1} + \frac{0.357w}{(2.639)}_{t-2} + \frac{0.962w^e}{(8.300)}_{t-1} + e_{2t} \quad (6.28)$$

### B.1.5

$$w_t = \frac{2.662}{(0.179)} + \frac{1.760(EDL II)}{(1.957)}_t + w_t^e + e_{3t} \quad (6.29)$$

$$w_t^e = \frac{-0.320w}{(1.876)}_{t-1} + \frac{0.349w}{(2.611)}_{t-2} + \frac{0.971w^e}{(8.791)}_{t-1} + e_{4t} \quad (6.30)$$

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29. The covariance required in the calculation of the t-ratio for the coefficient of  $w_{t-1}$  is  $\text{cov}(\hat{\alpha}, \hat{\gamma}) = -0.000174$  in the case of B.1.3 and  $\text{cov}(\hat{\alpha}, \hat{\gamma}) = -0.000466$  for B.1.5. See above, p. 175n.

## 6.6 Comparison of the Preferred Estimations of the Prototype Models

Two equally preferred estimations have been selected for each of the four prototype models in the course of the discussion of Sections 6.2 through to 6.5. These estimations are grouped together in Table 6.11 for the convenience of the reader. Their associated residuals correlograms appear in Table 6.12. The object of the current section is to determine, on the basis of these preferred estimations, whether any of the prototype models A.1, A.2, B.1 and B.2 is appropriate for the Australian economy and to select a preferred model from among the four. It will be noted that, in Table 6.11, the four EDL I preferred estimations appear first followed by the four EDL II preferred estimations. Discussion of the preferred estimations will also follow this order.

As has previously been noted the general quality of A.2.9 (Model A.2 in terms of the excess demand for labour proxy EDL I) is quite good. Three of the four structural parameters are significant at the 2.5 per cent level of significance or better,  $a_0$  being significantly different from zero at the 1 per cent level,  $a_1$  significantly positive at 2.5 per cent and  $\gamma$  significantly positive at 1 per cent. The autocorrelation parameter meets all requirements,<sup>30</sup>  $\rho_4$  being significantly different from zero, significantly greater than minus unity and significantly smaller than unity at the 1 per cent level of significance. As shown in Table 6.11, the 99 per cent confidence limits for  $\rho_4$  lie entirely inside the interval bounded by minus unity and zero. All the point estimates of A.2.9 (and of all

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30. See above, p. 125.

TABLE 6.11

Preferred NLLS Estimations of the Prototype Models<sup>a</sup>

Estimation Number	Variables in $f(u_t)$	Parameter						MSR	99% Confidence Limits for $\rho_4$
		$a_0$	$a_1$	$\alpha$	$\gamma$	$\delta$	$\rho_4$		
A.2.9	EDL I	4.152 <sup>*1</sup> (3.585)	1.404 <sup>*2.5</sup> (2.128)		0.289 <sup>*1</sup> (2.499)	0.536 (1.238)	-0.435 <sup>*1</sup> (3.353)	2.406	-0.101 -0.769
A.1.9	EDL I	3.139 <sup>*1</sup> (4.275)	1.137 <sup>*5</sup> (1.784)		0.253 <sup>*2.5</sup> (2.272)	1.000	-0.448 <sup>*1</sup> (3.533)	2.457	-0.121 -0.775
B.2.3	EDL I	3.661 (1.136)	1.600 <sup>*5</sup> (1.795)	-0.793 (0.578)	0.214 (0.987)	0.322 (0.624)	-0.509 <sup>*1</sup> (4.078)	2.330	-0.187 -0.831
B.1.3	EDL I	1.857 (0.198)	1.672 <sup>*5</sup> (1.892)	-0.357 <sup>*1</sup> (2.639)	0.038 (0.331)	1.000	-0.548 <sup>*1</sup> (4.704)	2.403	-0.248 -0.848
A.2.10	EDL II	4.277 <sup>*1</sup> (3.577)	1.506 <sup>*2.5</sup> (2.169)		0.280 <sup>*1</sup> (2.461)	0.466 (1.026)	-0.438 <sup>*1</sup> (3.384)	2.394	-0.105 -0.771
A.1.10	EDL II	3.125 <sup>*1</sup> (4.063)	1.182 <sup>*5</sup> (1.774)		0.240 <sup>*2.5</sup> (2.190)	1.000	-0.451 <sup>*1</sup> (3.557)	2.455	-0.124 -0.778
B.2.5	EDL II	4.097 (1.153)	1.742 <sup>*5</sup> (1.919)	-1.018 (0.415)	0.195 (1.002)	0.243 (0.430)	-0.512 <sup>*1</sup> (4.111)	2.317	-0.191 -0.833
B.1.5	EDL II	2.662 (0.179)	1.760 <sup>*5</sup> (1.957)	-0.349 <sup>*1</sup> (2.611)	0.029 (0.265)	1.000	-0.551 <sup>*1</sup> (4.759)	2.393	-0.253 -0.849

Note: a. Notes as in Table 6.3.



TABLE 6.12

Residuals Correlograms for Preferred NLLS Estimations of the Prototype Models<sup>a</sup>

Estimation Number	Estimated Autocorrelations $\hat{\psi}_k$ for lag, k =											
	1	2	3	4	5	6	7	8	9	10	11	12
A.2.9	-0.094 (0.701)	0.051 (0.381)	0.185 (1.381)	-0.032 (0.239)	-0.301 (2.246)	0.176 (1.313)	0.125 (0.933)	-0.123 (0.918)	0.127 (0.948)	-0.113 (0.843)	0.094 (0.701)	-0.208 (1.552)
A.1.9	-0.116 (0.866)	0.034 (0.254)	0.167 (1.246)	-0.044 (0.328)	-0.333 (2.485)	0.141 (1.052)	0.083 (0.619)	-0.166 (1.239)	0.077 (0.575)	-0.148 (1.104)	0.058 (0.433)	-0.256 (1.910)
B.2.3	-0.027 (0.200)	-0.092 (0.681)	0.158 (1.170)	-0.068 (0.504)	-0.374 (2.770)	0.170 (1.259)	0.195 (1.444)	-0.144 (1.067)	0.056 (0.415)	-0.055 (0.407)	0.068 (0.504)	-0.176 (1.304)
B.1.3	-0.069 (0.511)	-0.197 (1.459)	0.126 (0.933)	-0.091 (0.674)	-0.427 (3.163)	0.171 (1.267)	0.224 (1.659)	-0.173 (1.281)	0.012 (0.089)	-0.041 (0.304)	0.060 (0.444)	-0.193 (1.430)
A.2.10	-0.096 (0.716)	0.053 (0.396)	0.181 (1.351)	-0.034 (0.254)	-0.308 (2.299)	0.181 (1.351)	0.128 (0.955)	-0.127 (0.948)	0.122 (0.910)	-0.105 (0.784)	0.091 (0.679)	-0.206 (1.537)
A.1.10	-0.121 (0.903)	0.034 (0.254)	0.162 (1.209)	-0.047 (0.351)	-0.341 (2.545)	0.143 (1.067)	0.083 (0.619)	-0.173 (1.291)	0.069 (0.515)	-0.144 (1.075)	0.054 (0.403)	-0.258 (1.925)
B.2.5	-0.023 (0.170)	-0.083 (0.615)	0.155 (1.148)	-0.068 (0.504)	-0.374 (2.770)	0.177 (1.311)	0.199 (1.474)	-0.145 (1.074)	0.049 (0.363)	-0.048 (0.356)	0.067 (0.496)	-0.175 (1.296)
B.1.5	-0.066 (0.489)	-0.189 (1.400)	0.122 (0.904)	-0.092 (0.681)	-0.428 (3.170)	0.177 (1.311)	0.228 (1.689)	-0.175 (1.296)	0.001 (0.007)	-0.034 (0.252)	0.059 (0.437)	-0.191 (1.415)

Note: a. Figures in parentheses are absolute values of the approximate asymptotic t-ratios.

other estimations appearing in Table 6.11) are correctly signed on the basis of *a priori* considerations. The main defect of A.2.9 is the poor estimate of  $\delta$ , the coefficient of the expected inflation rate in the structural equation for  $w_t$  of Model A.2. The t-ratio associated with the point estimate of  $\delta$  is not quite large enough to accept the hypothesis that  $\delta$  is greater than zero at the 10 per cent level of significance.<sup>31</sup> In fact, quite widely differing hypotheses about  $\delta$  can be accepted. Perhaps the most important, apart from the hypothesis that it equals zero, acceptance of which at the 10 per cent level of significance is indicated by the remarks above, is the hypothesis that  $\delta$  equals unity which also can not be rejected even at the 10 per cent level of significance.<sup>32</sup> The 99 per cent confidence limits for  $\delta$  obtained from A.2.9 are -0.579 and 1.651. In view of the fact that  $\delta$  is poorly determined in A.2.9, Model A.2 *as it stands* could not be said to be appropriate for the Australian economy. However, all the other structural parameters of Model A.2 are very well determined. Thus, it seems that although the present form of Model A.2 is not entirely appropriate for the Australian economy, the model shows considerable promise. Further, it is probable that the defect in Model A.2 lies in the specification of the expectations-adjustment equation. According to that equation, the only influence on the adjustment or revision

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31. The t-ratio associated with the estimate of  $\delta$  is 1.238 while to accept the stated hypothesis the required t-ratio is 1.282.

32. The observed value of the test statistic  $(\hat{\delta} - 1)/\hat{\sigma}_{\hat{\delta}}$  is -1.072, while the acceptance region for the null hypothesis  $\delta = 1$  when the alternative hypothesis is  $\delta < 1$  is  $t < -1.282$ .

of inflationary expectations is the behaviour of the actual inflation rate. It may well be the case that other influences are important in the formation of inflationary expectations. This question will be put aside for the time being and considered in Chapter Seven.

Model A.1 cannot be considered appropriate for the Australian economy unless Model A.2 is appropriate because Model A.1 is the special case of Model A.2 for which  $\delta$  equals unity. Since we have already concluded that Model A.2 is inappropriate we must, therefore, say the same of Model A.1, regardless of the properties of the preferred estimation A.1.9.

Only one of the structural parameters of Model B.2 turns out to be significant on the basis of B.2.3. The parameter in question is  $a_1$  which is significantly positive at the 5 per cent level. In particular, none of  $\alpha$ ,  $\gamma$  or  $\delta$  is significant even at the 10 per cent level. Accordingly, Model B.2 cannot be considered appropriate for the Australian economy and since Model B.1 is just a special case of Model B.2, Model B.1 must be regarded as inappropriate also. This is so despite the fact that the performance of B.1.3 is superior to that of B.2.3.

On the basis of the estimations in which EDL I is involved it appears, therefore, that none of the prototype models is appropriate for the Australian economy. Further, only Model A.2 can be considered as clearly showing promise on the basis of the empirical work undertaken here. It has already been noted that for any given model there is invariably a marked similarity between the estimation in terms of EDL I and that in EDL II. That this is the case for the preferred estimations can easily be verified by referring to Table 6.11.

Accordingly the conclusions regarding the appropriateness of the prototype models arrived at on the basis of the preferred EDL I estimations (A.2.9, A.1.9, B.2.3 and B.1.3), hold also for the preferred EDL II estimations (A.2.10, A.1.10, B.2.5 and B.1.5).

It remains only to select a preferred model. It is fairly clear on the basis of the preferred estimations presented in Table 6.11 that the prototype models can be ranked in the order A.2, A.1, B.1 and B.2. As such A.2 is the preferred prototype model. Note however that in view of the remarks made earlier this preference for Model A.2 does not imply rejection of the other three prototype models.

It will be recalled from Chapters One and Two that two of the main reasons for interest in the expectations hypothesis are that it gives rise to the important distinction between the short-run and long-run inflation-unemployment trade-offs and that the associated issue concerning the existence of a non-degenerate long-run trade-off is as yet unresolved. It is appropriate therefore to examine the short-run and long-run trade-offs implied by the estimations of the preferred prototype model - A.2. The final estimates of the wage equation of Model A.2 are as follows.

$$\text{From A.2.9, } w_t = 4.152 + 1.404(\text{EDL I})_t + 0.535p_t^e + e_t \quad (6.31) \\ (3.585) \quad (2.128) \quad (1.238)$$

$$\text{From A.2.10, } w_t = 4.277 + 1.506(\text{EDL II})_t + 0.466p_t^e + e_t \quad (6.32) \\ (3.577) \quad (2.169) \quad (1.026)$$

In view of the fact that these estimated wage equations run in terms of EDL I and EDL II rather than the unemployment rate  $u$ , nothing can be said directly about the inflation-unemployment trade-offs as such.

However, it is possible to obtain estimates of the short-run and long-run "trade-offs"<sup>33</sup> between inflation and EDL. In view of the fact that the unemployment rate and *EDL* are systematically related,<sup>34</sup> these estimates can then be used to obtain estimates of the short-run and long-run trade-offs between inflation and *unemployment* indirectly.

It is important to realize that any estimates of the trade-offs based on the estimates in A.2.9 and A.2.10 must be viewed with caution. This is so because it has already been concluded that prototype Model A.2 is not entirely appropriate for the Australian economy. In the case of the estimation of the long-run trade-off there is an additional reason to exercise caution. In A.2.9 and A.2.10, the t-ratio associated with the coefficient of the expected rate of inflation is low and the confidence limits for that coefficient will therefore be relatively wide. As this coefficient is required in the calculation of an estimate of the long-run trade-off, its low t-ratio represents an additional reason for viewing the estimate of the long-run trade-off with caution. These remarks notwithstanding, estimates of the trade-offs will be obtained on the assumption that the point estimates in A.2.9 and A.2.10 can be taken *at their face value*.

Consider initially the point estimates from A.2.9 which runs in terms of EDL 1. It follows from (6.31) that  $\partial w / \partial EDL = 1.404$ ,

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33. Although we will continue to refer to a "trade-off" between inflation and EDL, the term is not strictly applicable because an increase in EDL will lead to an increase in *w* and hence in *p*, not a decrease as is required for the normal usage of the term trade-off to apply.

34. This follows from the definition of EDL. See above, pp. 133-136.

i.e. that a one point increase in EDL will lead, in the short-run, to an increase of about 1.4 percentage points in the rate of wage-inflation and hence in the rate of inflation via the mark-up price equation  $p = w - q$ . As noted above, this trade-off is not interesting of itself and the next step is therefore to translate it into an inflation-unemployment trade-off. For this purpose it is necessary to hark back to the development of the Hagger-Rayner EDL index.<sup>35</sup> It will be recalled that, when positive, EDL is calculated from

$$100 \left( \frac{v}{s} - m \right) \quad (6.33)$$

and, when negative, EDL is calculated from

$$100(m - u') \quad (6.34)$$

where  $u' = u/100$ . It is also the case that

$$s = \frac{vu'}{m} \quad (6.35)$$

and that the series were based on the "constant  $m$  approach" using the value  $m = 0.0222$ . Using (6.35), we have from (6.33) that, *when EDL is positive*,

$$EDL = 100 \left( v \cdot \frac{m^2}{vu'} - m \right)$$

Substituting  $m = 0.0222$  into this expression, eliminating  $v$  and manipulating, we get:

$$EDL = 4.928u^{-1} - 2.22 \quad (6.36)$$

*when EDL is positive*. Similarly, from (6.34) we obtain:

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35. See above, pp. 133-136.

$$EDL = 2.22 - u \quad (6.37)$$

when *EDL* is negative.

When *EDL* is positive,

$$\frac{\partial w}{\partial u} = \frac{\partial w}{\partial EDL} \cdot \frac{dEDL}{du} = (1.404)(-4.928u^{-2})$$

from (6.31) and (6.36). Equating  $\partial p/\partial u$  and  $\partial w/\partial u$  by virtue of the mark-up price equation  $p = w - q$ , when *EDL* is positive,

$$\frac{\partial p}{\partial u} = -6.919u^{-2} \quad (6.38)$$

Similarly, from (6.31) and (6.37), it follows that when *EDL* is negative,

$$\frac{\partial p}{\partial u} = -1.404 \quad (6.39)$$

It remains to establish the unemployment rates for which (6.38) and (6.39) apply. This is a relatively simple matter in view of the definition of the maladjustment  $m$  as the level of unemployment consistent with zero excess demand for labour.<sup>36</sup> Since  $m = 0.0222$ , it follows that (6.38) applies for unemployment rates smaller than or equal to 2.22 per cent and (6.39) applies for all other unemployment rates. Hence, in the short-run, a one-point increase in the unemployment rate will lead to a decrease of about 6.9 percentage points in the rate of inflation when the unemployment rate is 1.0 per cent. At 1.5 per cent unemployment this figure is about 3.1, at 2.0 per cent it is about 1.7 while for all unemployment rates greater than 2.22 per cent it is about 1.4.

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36. See above, p. 133.

Turn now to the long-run trade-off implied by the point estimates from A.2.9. Substituting (6.31) into the mark-up price equation  $p = w - q$  (and dropping the residual) we get:

$$p = 4.152 + 1.404EDL + 0.536p^e - q \quad (6.40)$$

A consequence of the specification of the expectations-adjustment equation of Model A.2 is that  $p = p^e$  in the long-run.<sup>37</sup> Using this equality in (6.40) gives the following estimated long-run relationship between  $p$  and  $EDL$ .

$$p = 8.948 + 3.026EDL - q$$

Hence, in the long-run  $\partial p / \partial EDL = 3.026$ . Using (6.36) and arguing as before, it then follows that in the long-run, *when EDL is positive*

$$\frac{\partial p}{\partial u} = -14.913u^{-2} \quad (6.41)$$

Similarly, using (6.37), in the long-run, *when EDL is negative*,

$$\frac{\partial p}{\partial u} = -3.026 \quad (6.42)$$

As before, (6.41) applies when the unemployment rate is smaller than or equal to 2.22 per cent and (6.42) applies for all other unemployment rates. Hence, *in the long-run*, a one-point increase in the unemployment rate will lead to a decrease of about 14.9 percentage points at an unemployment rate of 1.0 per cent. At 1.5 per cent unemployment this figure is about 6.6, at 2.0 per cent it is about

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37. See above, p. 26.



3.7 while for all unemployment rates greater than 2.22 per cent it is about 3.0.

An exercise similar to that just undertaken for the point estimates from A.2.9, can also be performed for those from A.2.10. The results are as follows. In the *short-run*, a one-point increase in the unemployment rate will lead to a decrease of about 7.4 percentage points in the rate of inflation at an unemployment rate of 1.0 per cent. At unemployment rates of 1.5 and 2.0 per cent this figure is 3.3 and 1.9 respectively. At all unemployment rates greater than 2.22 per cent it is 1.5. In the *long-run*, the corresponding figures are 13.9, 6.2 and 3.5 at 1.0, 1.5 and 2.0 per cent unemployment respectively, while it is 2.8 for all unemployment rates greater than 2.22.

Taken at their face value, these estimates of the inflation-unemployment trade-offs indicate that there is an appreciable short-run trade-off, especially at low unemployment rates in the vicinity of 1.5 to 2.0 per cent of the labour force. At 2.0 per cent unemployment, for instance, the short-run effect of a one point increase in the unemployment rate is a decrease of nearly two percentage points in the rate of inflation. The estimates also indicate that there exists for Australia a non-degenerate long-run trade-off between inflation and unemployment, although of course the long-run trade-off is considerably steeper than that which applies in the short-run. Finally, it is important to again add the rider that these conclusions must be viewed with caution in that they are based on point estimates, taken at face value, of prototype Model A.2 which, although it was selected as the preferred model, was found not to be entirely appropriate for the Australian economy.

## CHAPTER SEVEN

### MODIFICATIONS OF THE PROTOTYPE MODELS

#### 7.1 Introduction

The main conclusion of Chapter Six was that none of the prototype expectations-hypothesis models discussed in Chapter Two is appropriate in its existing form for the Australian economy. It was also noted in Chapter Six that only Model A.2 showed much promise on the basis of its current specification. The object of the present chapter is to consider a number of modifications of the prototype models which have been proposed in recent years and to select those which appear worthy of attention in the context of the Australian economy.

The modifications concerned can be conveniently placed into three groups - those which affect the price equation, those which affect the wage equation and those which affect the expectations-adjustment equation. The first of these three groups will be discussed in the next section and the second and third in sections 7.3 and 7.4 respectively.

To limit the discussion, it was decided that a particular change would be regarded as a "modification" (and hence would need to be discussed) only if the revised model would still retain the essential features of the prototype models and be unmistakably in the expectations-hypothesis spirit. Application of this criterion put the numerous general price-equation and wage-equation studies of recent years outside the scope of the chapter.

## 7.2 Modifications of the Price Equation

The role of the price equation in the prototype models is relatively minor in that it serves only as a link between the rate of wage-inflation ( $w$ ) and the rate of inflation ( $p$ ). In particular, no expectations variable appears in the price equation. Models which are unmistakably in the spirit of the prototype models but which have the expected rate of inflation as a variable in the price equation, have, however, been considered, notably by Solow [120] and Laidler [69]. In both of these studies the modified price equation appears to the exclusion of a wage equation. This, however, is not at all essential; there is no reason why a modified price equation of the type under discussion should not appear in an expectational model with a wage equation similar to the one included in the prototype models.

Solow's [120] work was discussed in detail in Chapter Three and it is unnecessary to consider it again here. Suffice it to say that the price equation Solow suggests takes the form<sup>1</sup>

$$p = a_0 + a_1 w + a_2 Z_1 + a_3 Z_2 + \dots + \delta p^e \quad (7.1)$$

where  $Z_1, Z_2, \dots$  denote the "... relevant real characteristics like the unemployment rate, the level of output, and any others." [120, p. 3] Solow's justification for a price equation of this form is essentially the view expressed by Friedman [30] that only "... the unanticipated part of current inflation [ $p - p^e$ ] has any gearing to the real part of the economy." [30, p. 3]

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1. The notation conforms to that used throughout the thesis and is slightly different from Solow's.

Laidler [69] takes a somewhat different view. He postulates that "... the rate at which firms mark up their prices over time, when markets are in equilibrium and full employment prevails, is equal to the expected rate of inflation. In the presence of general excess supply firms raise their prices by less than the expected inflation rate and, faced by general excess demand, they raise their prices by more." [69, p. 370] This leads Laidler to a price equation of the form<sup>2</sup>

$$p_t = \gamma y_{t-1} + p_{t-1}^e \quad (7.2)$$

where, as before,  $y$  is the ratio of real income to its full employment level and is introduced as a proxy for excess demand. Elsewhere, Laidler [70] provides a related but alternative explanation for a very similar price equation. He notes that "The basis of the so-called 'New Micro-economics' is that market participants have less than perfect information about the prices and quantities at which markets will clear." [70, p. 63] It is necessary in these circumstances for firms "... to form the best expectations they can, call out their own prices on the basis of these expectations, and then, in response to the quantities bought and sold at these prices, revise their expectations and hence the prices they call." [70, pp. 63-64]

It should be noted that Solow's price equation (7.1) can be looked upon as combining a wage equation of the form which appears in the prototype models and a modified price equation, the expectations

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2. Laidler's price equation has been modified slightly to conform with the conventions and notation adopted for the purposes of this thesis.

variable actually entering via the determination of the rate of wage-inflation and the rate of inflation being determined in consequence by way of a mark-up mechanism. The same cannot be said, however, of Laidler's price equation (7.2). Expectations influence the formation of prices and hence the rate of inflation directly there and, in fact, the rate of wage-inflation does not appear anywhere in either of the two Laidler models [69 and 70] mentioned.

### 7.3 Modifications of the Wage Equation

Whereas there is relatively little that can be done to modify the form of the price equation, there is a good deal more scope for modification and extension in the case of the wage equation. In general, the wage equation of the prototype models takes one of the following two forms.

$$w = f(u) + \delta p^e \quad (7.3)$$

$$w = f(u) + \delta w^e \quad (7.4)$$

It follows immediately that there are two directions in which the wage equation may be modified - by altering the way in which labour excess demand (proxied by  $f(u)$  in (7.3) and (7.4)) enters the wage equation or by modifying the expectations variable.

As regards the former, Godfrey and Taylor [32] argue that labour excess supply (or equivalently labour excess demand) proxies based on registered unemployed are inadequate because labour which is in employment but is under-employed ("hoarded" labour) also

represents a component of the excess supply of labour. The same criticism can also be directed at labour excess demand proxies based on statistics relating to unemployed persons (whether or not they are *registered* as unemployed) and job vacancies. The omission of hoarded labour from labour excess demand is material, however, only if it influences the rate of wage-inflation in a systematic way. Godfrey and Taylor found that labour hoarding was a significant determinant of the rate of wage-inflation in the United Kingdom for the period 1954 to 1970. Whether this conclusion also applies to Australia is a matter for empirical investigation.

McCallum [75] suggests a procedure which allows the excess demand for labour to be eliminated entirely from the wage equation and replaced by its ultimate determinants. The determinants of the supply and demand for labour can be specified at any desired level of generality and an expression derived for the excess demand for labour which runs only in terms of observable variables. For instance, McCallum assumes that the quantity of labour demanded in period  $t$ ,  $L_t^D$ , is given by

$$\frac{L_t^D}{Q_t} = f(W_t, t) \quad (7.5)$$

where  $Q$  denotes aggregate output and  $W$  denotes the real wage rate. The trend variable  $t$  is included to account for technical progress. The quantity of labour supplied in period  $t$ ,  $L_t^S$ , is assumed to conform to

$$\frac{L_t^S}{N_t} = g(W_t, t) \quad (7.6)$$

where  $N$  denotes population and  $t$  is included "... to capture the

influence of gradually changing tastes for employment and other institutional factors." [75, p. 270] Adopting log-linear forms for (7.5) and (7.6), it follows that

$$\log L_t^D - \log L_t^S = b_1 + \log q_t + b_2 \log W_t + b_3 t \quad (7.7)$$

where  $q$  denotes  $Q/N$ . The terms on the left-hand side of (7.7) can be interpreted as an approximation to the relative excess demand for labour,  $(L^D - L^S)/L^S$ . Accordingly the right-hand side of (7.7) can be substituted for labour excess demand in the wage equation, thus allowing its influence to be taken into account without the need for proxy variables. The form of (7.7) is, of course, entirely conditional on the specifications adopted for the labour supply and demand functions (7.5) and (7.6). For this reason, the usefulness of the procedure suggested by McCallum is dependant on the realism of those specifications.

Several authors have suggested modifying the way in which the expectations variable enters the wage equation. Gordon [39] examines the possibility that the expected inflation rate might enter the wage equation with a variable coefficient. When the rate of inflation is low it is likely that employees will not consider compensation for anticipated inflation particularly important when making a wage bargain. The higher is the rate of inflation and especially the higher is the expected rate of inflation, the more employees suffer in terms of real purchasing power when they are not compensated for anticipated inflation and therefore the more importance they will place upon such compensation in their wage bargains. Two facets of this sort of behaviour can be identified.

There is a "threshold effect" which results in the coefficient of the expected rate of inflation being zero when the expected rate of inflation is smaller than some critical level or threshold.

In addition there is a "consciousness effect" by which the degree of compensation for anticipated inflation and hence the coefficient of the expected rate of inflation in the wage equation is itself an increasing function of the expected rate of inflation.<sup>3</sup> These two effects can be incorporated by writing the wage equation in the form

$$w_t = f(u_t) + h(p_t^e)p_t^e \quad (7.8)$$

where the function  $h(p_t^e)$  satisfies  $h' \geq 0$  to capture the consciousness effect and  $h(p_t^e) = 0$  for  $p_t^e \leq R$ , where  $R$  is a positive constant, to accommodate the threshold effect. On the presumption that more than full compensation for anticipated inflation can be ruled out, it is also the case that  $h(p_t^e) \leq 1$  and  $h(p_t^e) = 1$  for some  $p_t^e = L$  although it is not possible *a priori* to say whether  $L$  is finite or infinite. Finally, it is necessary that  $h(p_t^e) \geq 0$ .

Gordon specifies the form of  $h(p_t^e)$  in (7.8) as

$$h(p_t^e) = \begin{cases} cp_t^e, & 0 \leq p_t^e < 1/c \\ 1.0, & p_t^e \geq 1/c \end{cases} \quad (7.9)$$

In adopting this specification for  $h(p_t^e)$ , Gordon has excluded the possibility of a threshold effect. His specification also fails to

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3. Gordon considers only the consciousness effect. See [39] especially pp. 404-406.



meet the non-negativity requirement on  $h(p_t^e)$ . The main advantage of (7.9) is that when substituted into (7.8), the resulting equation is

$$w_t = f(u_t) + c(p_t^e)^2 \quad (7.10)$$

which is easy to handle empirically when the PE approach<sup>4</sup> is employed, as is the case for Gordon's work. While it is clear that the form of  $h(p_t^e)$  adopted by Gordon is not completely satisfactory, it is not easy to devise an alternative specification which meets all the restrictions on  $h(p_t^e)$  and quite difficult to find a suitable *continuous* specification which captures both the threshold and consciousness effects. To meet all the restrictions imposed on  $h(p_t^e)$ , the specification adopted must take one of the forms shown in Figure 7.1. Both forms involve at least one discontinuity which poses considerable problems from the point of view of estimation. It is possible, however, to approximate both forms with a continuous function. One such specification<sup>5</sup> is the following.

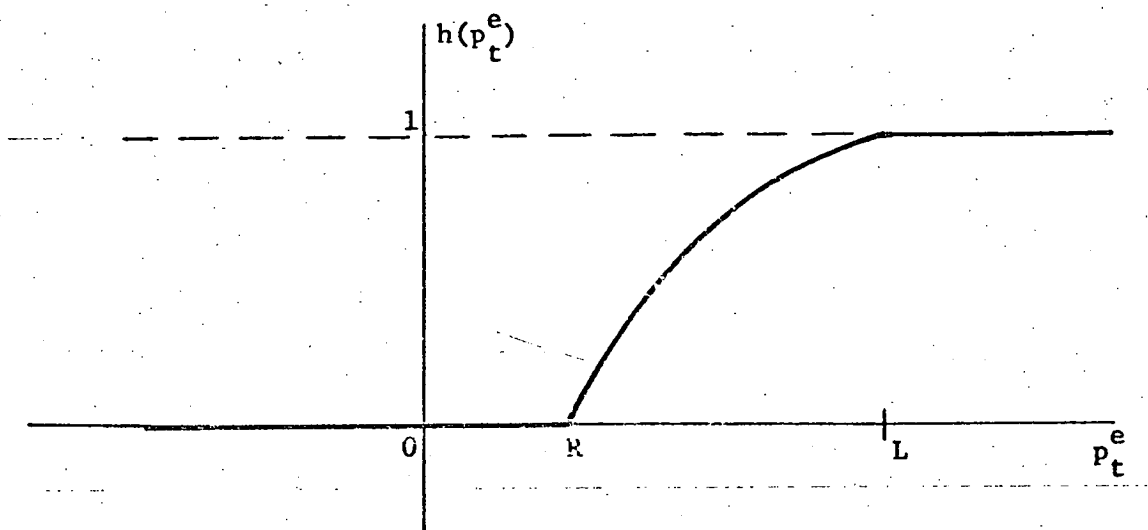
$$h(p_t^e) = \int_{-\infty}^{p_t^e} \frac{1}{\sqrt{2\pi}\sigma} \exp\left\{-\frac{1}{2} \left(\frac{\xi - \mu}{\sigma}\right)^2\right\} d\xi \quad (7.11)$$

The form of the function specified in (7.11) is shown in Figure 7.2. It involves only two unknown parameters,  $\mu$  and  $\sigma$ ,  $\mu$  determining the point at which the inflexion occurs and  $\sigma$  determining the slope of the non-linear part of the function. Although the appearance of the integral in (7.11) makes the estimation of the parameters  $\mu$  and

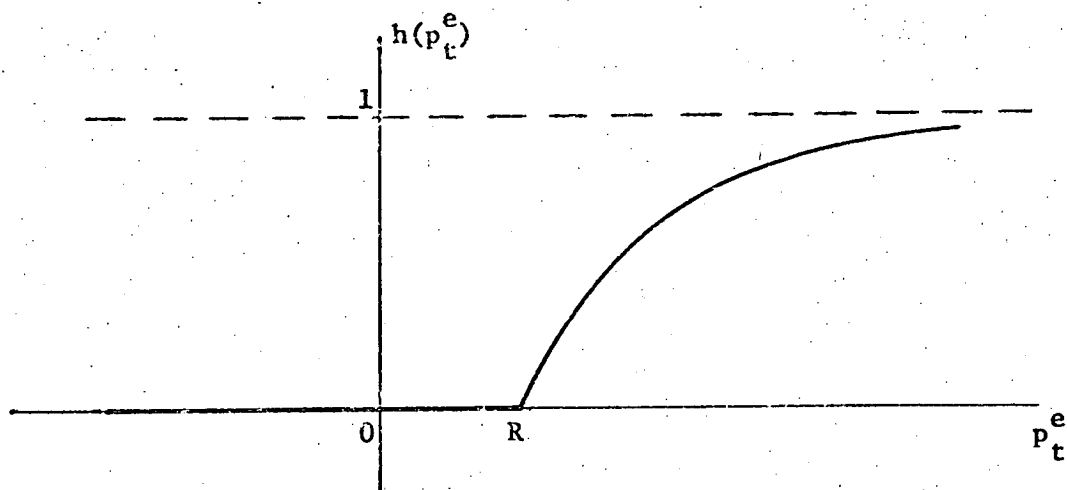
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4. cf. pp. 101-2.

5. See Goldfeld and Quandt [35], pp. 263-264. The functional form is the cumulative normal integral.



(a) Finite L



(b) Infinite L

Figure 7.1

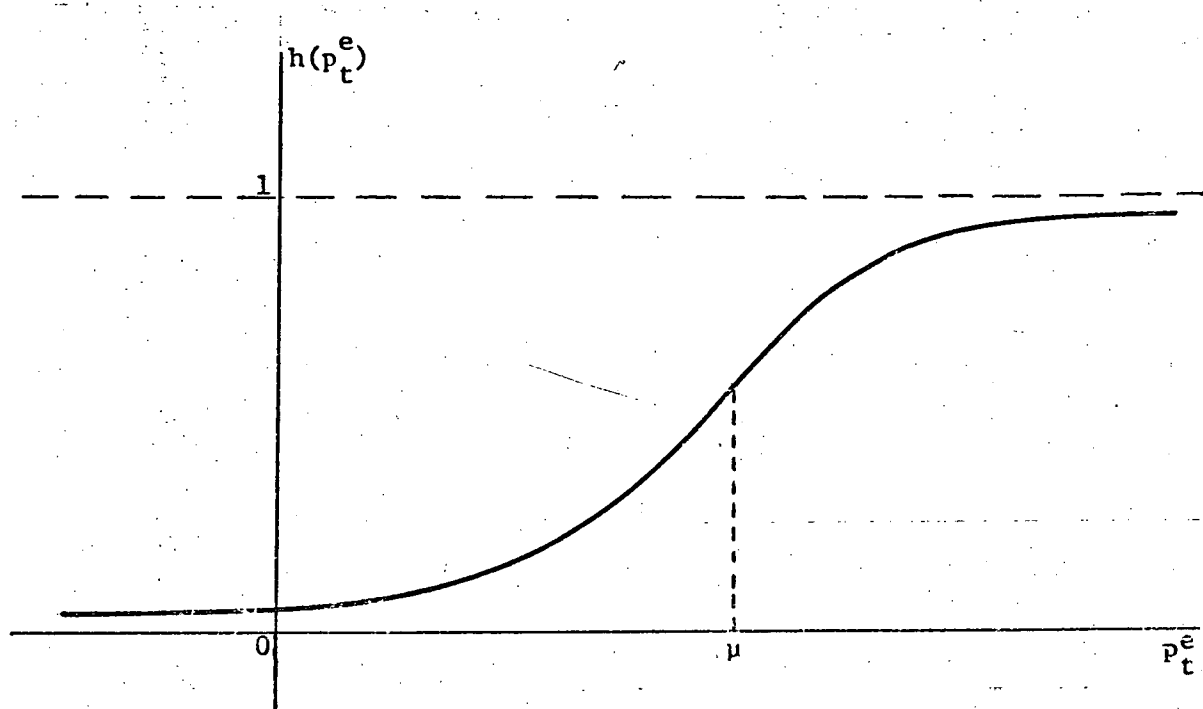


Figure 7.2

or difficult, Goldfield and Quandt [35, pp. 265-273] report some very promising experiments with a function of this form.

The expectations variable which appears in the wage equation of the prototype model B is the expected rate of wage-inflation. Sumner [122] has suggested the following treatment of that expectations variable. He assumes at the outset that the expected wage ( $W^e$ ) is equal to the expected value of the marginal product of labour ( $M^e$ ), that is,

$$W^e = M^e \quad (7.12)$$

By definition, the expected value of the marginal product of labour is the product of the expected price level ( $P^e$ ) and the expected marginal physical product of labour ( $N^e$ ),

$$M^e = N^e \cdot P^e \quad (7.13)$$

Finally, it is assumed that the expected marginal physical product of labour is proportional to the expected average physical product of labour ( $Q^e$ ),

$$N^e = \theta Q^e \quad (7.14)$$

Substitution of (7.13) and (7.14) into (7.12) gives

$$W^e = \theta Q^e P^e \quad (7.15)$$

from which it follows that

$$\ln W^e = \ln \theta + \ln Q^e + \ln P^e \quad (7.16)$$

Differentiating (7.16) with respect to time produces

$$\dot{W}^e = \dot{Q}^e + \dot{P}^e \quad (7.17)$$

where for example  $\dot{W}^e$  denotes the proportional rate of change of  $W^e$ . Sumner then substitutes  $\dot{Q}^e + \dot{P}^e$  for  $w^e$  in the wage equation. In doing so he is placing the same interpretation on  $\dot{W}^e$  as on  $w^e$ . This is not strictly valid, however, because  $\dot{W}^e$  is the rate of change of the expected wage whereas  $w^e$  is the expected rate of change of wages - expectations are being formed about different things. Leaving aside this point, Sumner's next step is to add an adaptive expectations equation for each of  $\dot{P}^e$  and  $\dot{Q}^e$ . Thus his procedure comes down to replacing  $w^e$  by the sum of  $\dot{P}^e$  and  $\dot{Q}^e$  and replacing the adjustment equation for  $w^e$  by a similar equation for each of  $\dot{P}^e$  and  $\dot{Q}^e$ . The main advantage claimed for Sumner's procedure is that it "... provides an explicit rationale for introducing the rate of change of labour productivity into the Phillips relation, whereas

other models which have employed this variable as an argument in the wage equation have been constructed on a purely *ad hoc* basis." [122, p. 173] The main objections to the procedure are the questionable equation of the expected rate of wage-inflation with the rate of change of expected wages and the assumed proportionality between the expected average and expected marginal products of labour.<sup>6</sup>

Parkin, Sumner and Ward [97] have developed an expectational model which, while being unmistakably in the spirit of the prototype models, is derived in a rather different way. Parkin, Sumner and Ward (hereafter PSW) concentrate on the roles of domestic and foreign inflationary expectations and of taxation both on employees and on employers. The PSW model is based on the following premises.

"First, the supply of labor by households to a particular sector of the economy depends on the effective real wage received by the household. This real wage will be the ratio of the money wage net of all taxes to an average price of consumer goods gross of all indirect taxes (and net of subsidies). Second, the demand for labor by firms depends on the ratio of the gross cost of labor (the wage rate gross of direct taxes plus employers' social security taxes) to the net price of output received by firms. Third, the wage level is set by a bargaining process between labor unions and employers' federations with the objective of achieving and maintaining a cleared market." [97, pp. 6-7] It is then shown by PSW<sup>7</sup> that these

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6. If the aggregate production function is Cobb-Douglas then the average and marginal products of labour are proportional. It is questionable however whether proportionality carries over to the expected products. In any event the assumption that the aggregate production function is Cobb-Douglas is itself open to question.
  7. See [97], pp. 7-9. The notation used here differs slightly from that of PSW.

premises lead to the following wage equation for a closed economy.

$$w = \alpha_1 x + \alpha_2 p_E^e + \alpha_3 (p_C^e + T_4^e) + \alpha_4 T_1^e + \alpha_5 (T_2^e + T_3^e) \quad (7.18)$$

with  $\alpha_2 = -\alpha_4$ ,  $\alpha_3 = -\alpha_5$ ,  $\alpha_2 + \alpha_3 = 1$ ,  $\alpha_4 + \alpha_5 = -1$ , and where  $x$  denotes labour excess demand,  $p_E^e$  the expected rate of change of prices received by employers,  $p_C^e$  the expected rate of change of prices (net of indirect taxes) paid by consumers,  $T_1^e$  the expected proportional change of unity plus the effective rate of employers' social security contributions,  $T_2^e$  the expected proportional change of unity minus the effective rate of employees' social security contributions,  $T_3^e$  the expected proportional change of unity minus the effective rate of income tax and  $T_4^e$  the expected proportional change of unity plus the effective rate of indirect tax. The features of this wage equation are the explicit recognition of the difference between the price paid by consumers and the price received by employers, and the difference between the effective wage rate for employers and that for employees.

PSW then extend their model to take international influences into account by assuming that firms can sell at different prices in the domestic market and in the foreign market. This leads them<sup>8</sup> to the following wage equation for an open economy.

$$w = \alpha_1 x + \alpha_2 p_E^e + \alpha_3 p_F^e + \alpha_4 p_C^e + \alpha_5 T_1^e + \alpha_6 (T_2^e + T_3^e) \quad (7.19)$$

with  $\alpha_2 + \alpha_3 + \alpha_4 = 1$ ,  $\alpha_5 + \alpha_6 = -1$ ,  $\alpha_4 = -\alpha_6$ , and where  $p_E^e$  denotes the expected rate of change of prices received by employers from the domestic market,  $p_F^e$  the expected rate of change of prices received

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8. See [97], p. 10. The notation is again a little different from PSW's.

by employers from the foreign market and all other notation is as explained previously.

While the wage equations which PSW arrive at are unmistakably expectational in form, they are considerably more complex than those of the prototype models. Furthermore, by virtue of the derivation of these wage equations there can be no question about which expectations variable is the relevant one. The considerations which lead to the distinction between the prototype models A and B ( $p^e$  entering the Model A wage equation while  $w^e$  enters that of Model B) do not apply to the PSW model.

The modifications and extensions of the wage equations of the prototype models considered thus far have all had a theoretical basis. There are, however, certain other modifications, which may be worthwhile, based entirely on empirical considerations. For example, the theory on which the expectations hypothesis and its variants rests is silent on the question of lags in the response the rate of wage-inflation to the excess demand for labour. It is likely, however, that this response is not an instantaneous one and may well be distributed over a number of periods. The question of lags in the response of the rate of wage-inflation to the excess demand for labour can be resolved only empirically.

As a second example, it has not yet been possible to resolve the question of which expectations variable should appear in the wage equation of an expectational model. It has been suggested by Godfrey and Taylor [32, p. 208] that the question might be settled by examining the significance of the coefficients of the expectations variables in a hybrid model in which the wage equation contains both

$p^e$  and  $w^e$  and which includes two expectations adjustment equations, one for each of  $p^e$  and  $w^e$ .

#### 7.4 Modifications of the Expectations-Adjustment Equation

Interest in the expectations-adjustment equation has been stimulated in recent years by several studies in which methods for obtaining an actual series for  $p^e$  (or  $w^e$ ) have been devised and then applied to some particular country. Typically these studies have used the  $p^e$  series so generated to consider the specification of the expectations-adjustment equation as such, rather than as part of an expectational model. Nevertheless their results are highly relevant in this context, as we shall see.

Two main forms of the expectations adjustment equation were considered in earlier chapters in the context of the prototype models, namely the first-order adaptive scheme

$$p_t^e - p_{t-1}^e = \gamma(p_{t-1} - p_{t-1}^e) \quad 0 \leq \gamma \leq 1 \quad (7.20)$$

and the first-order extrapolative scheme

$$p_t^e = p_{t-1} + \alpha(p_{t-1} - p_{t-2}) \quad (7.21)$$

It was noted in Section 4.2 that certain simpler schemes are contained as special cases of these schemes. In particular, static expectations  $p_t^e = p_{t-1}$  is the special case of the first-order adaptive scheme obtained when  $\gamma = 1$  and of the first-order extrapolative scheme when  $\alpha = 0$ .

Broadly speaking, the modifications available for the expectations adjustment equation fall into three groups: (i) those



which extend the adaptive and extrapolative schemes to higher order schemes, (ii) those which generalize the equation by specifying it as a distributed lag relationship of a less restrictive form than that implied by the adaptive or extrapolative schemes and (iii) those which allow the formation of expectations to be influenced by variables other than those about which the expectations in question are being formed. Although some of the relevant literature spans more than one of these broad groups or defies classification, as far as possible the discussion of this section will be conducted under these three heads.

Turnovsky [130], Carlson and Parkin [11 and 12] and Danes [16] have all considered both the first and second-order forms of each of the adaptive and extrapolative schemes.<sup>9</sup> In each case the study was concerned only with the formation of inflationary expectations and an observed inflationary expectations series was used. Turnovsky's [130] study considers the formation of price expectations in the United States for the period 1954 to 1969. The price expectations series used being the one collected by J. A. Livingston of the *Philadelphia Bulletin*.<sup>10</sup> In addition to the straight adaptive and extrapolative schemes, Turnovsky also considered the possibility that the unemployment rate, as an indicator of current economic activity, might influence the formation of price expectations. To take account of this possibility he tested a modified extrapolative scheme of the form<sup>11</sup>

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9. See above, p. 109n. for the specification of these schemes.

10. See above, pp. 91-92 for a discussion of the Livingston series.

11. The notation is not the same as Turnovsky's.

$$p_t^e = p_{t-1} + \alpha_1(p_{t-1} - p_{t-2}) + \alpha_2 u_t$$

and a modified adaptive scheme of the form

$$p_t^e - p_{t-1}^e = \gamma_1(p_{t-1} - p_{t-1}^e) + \gamma_2(u_{t-1} - u_{t-1}^*)$$

where  $u_t$  denotes the unemployment rate and  $u_t^*$  the forecast of the unemployment rate of quarter  $t$  made in quarter  $t-1$ .<sup>12</sup> Underlying the modified adaptive scheme is the hypothesis that price expectations are adapted not only to errors in past price expectations but also to errors in past forecasts of the unemployment rate.

Both the extrapolative and adaptive schemes can be looked upon as distributed lag relationships. The first-order extrapolative scheme (7.21) can be written as

$$p_t^e = (1 + \alpha)p_{t-1} - \alpha p_{t-2} \quad (7.22)$$

which is a two period distributed lag on  $p$  in which the weights sum to unity. It can also be shown<sup>13</sup> that the first-order adaptive

12. Both relationship and the associated discussion have been recast to produce conformity with the preceding discussion.

13. (7.20) rearranges into  $p_t^e = \gamma p_{t-1} + (1 - \gamma)p_{t-1}^e$ . Lagging one period produces

$$p_{t-1}^e = \gamma p_{t-2} + (1 - \gamma)p_{t-2}^e$$

which can be substituted into the expression for  $p_t^e$  to give

$$p_t^e = \gamma p_{t-1} + \gamma(1 - \gamma)p_{t-2} + (1 - \gamma)^2 p_{t-2}^e$$

Similarly,  $p_{t-2}^e = \gamma p_{t-3} + (1 - \gamma)p_{t-3}^e$

so that

$$p_t^e = \gamma p_{t-1} + \gamma(1 - \gamma)p_{t-2} + \gamma(1 - \gamma)^2 p_{t-3} + (1 - \gamma)^3 p_{t-3}^e$$

In view of the restriction  $0 \leq \gamma \leq 1$ , continuing in this way we eventually arrive at (7.23).

scheme (7.20) can be written as

$$p_t^e = \gamma p_{t-1} + \gamma(1 - \gamma)p_{t-2} + \gamma(1 - \gamma)^2 p_{t-3} + \dots \quad (7.23)$$

which is an infinite geometric distributed lag on  $p$ , with the weights on  $p_{t-1}$ ,  $p_{t-2}$ , ... summing to unity.<sup>14</sup> Similar results can be obtained for the second-order adaptive and extrapolative schemes.

In view of the interpretation of the adaptive and extrapolative schemes as distributed lags on  $p$ , an obvious generalization is to consider an expectations formation mechanism of the form

$$p_t^e = \sum_{j=0}^{\infty} \omega_j p_{t-j} \quad (7.24)$$

For reasons which will be clear from the discussion associated with (7.22) and (7.23), those cases of (7.24) for which  $\sum_{j=0}^{\infty} \omega_j = 1$  are of special interest. Turnovsky considers only the special case of (7.24) for which  $\omega_0 = 0$  and  $\omega_j = 0$  for  $j > Q$  where  $Q$  takes one of the values 4, 5 or 6.

Carlson and Parkin's [11 and 12] studies are concerned with the formation of inflationary expectations in the United Kingdom for the period 1961 to 1973. Their observed inflationary expectations series is based upon a monthly Gallup Poll survey of the expectations of about 1,000 individuals. They considered the first and second-order adaptive schemes and a generalized extrapolative scheme of the form

$$p_t^e = \alpha_0 + \sum_{i=1}^{12} \alpha_i p_{t-i}$$

which can be looked upon as a special case of (7.24) with an intercept included. In addition, Carlson and Parkin undertook an

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14. The sum of the weights is  $\gamma + \gamma(1 - \gamma) + \gamma(1 - \gamma)^2 + \dots$ .  
Since  $0 \leq \gamma \leq 1$  this sum equals  $\gamma/[1 - (1 - \gamma)] = 1$ .

extensive examination of the effects of variables other than  $p$  on the formation of inflationary expectations,  $p^e$ . Their approach was to estimate by OLS a relationship of the form

$$p_t^e = \gamma_0 + \sum_{i=1}^k \gamma_i x_{it} + v_t \quad (7.25)$$

The  $x_i$  were a set of some 23 "other variables" considered likely to influence the formation of inflationary expectations. The choice of these variables was based on two considerations. "First, economic theory suggests variables which might affect actual inflation and, hence, which might affect a rational person's expectation of it. Second, government policy aimed at controlling inflation via expectations suggest variables which, rightly or wrongly, may be believed to influence actual (and hence expected) inflation." [11, p. 20] These considerations lead Carlson and Parkin to consider the effect on the formation of inflationary expectations of the following six variables. (i) Changes in the foreign exchange rate, (ii) changes in the political party in power, (iii) wage-price controls, guidelines or norms, (iv) voluntary price restraint, (v) large and highly publicized wage increases and (vi) changes in indirect taxes. All but the last two of these variables are entered into (7.25) as dummy variables of one sort or another. The large and highly publicized wage increase variable takes the form

$$\bar{w}_t = \sum_i \frac{n_{it}}{N_t} \bar{w}_{it}$$

where  $\bar{w}_{it}$  denotes the rate of wage change in the  $i^{\text{th}}$  sector in period  $t$ ,  $n_{it}$  denotes the number of workers involved in the wage change  $\bar{w}_{it}$ , and  $N_t = \sum_i n_{it}$  is the total number of workers involved in wage settlements in period  $t$ . The data required to construct  $\bar{w}$

is available for the United Kingdom from the *Calendar of Economic Events* compiled by the National Institute for Economic and Social Research. The final variable, changes in indirect taxes, was defined as taking the value of the percentage change in the rates of purchase tax on consumer durables in the month in which a change is announced and zero otherwise. On the basis of the estimates of the parameters appearing in (7.25), Carlson and Parkin concluded that the 1967 devaluation had a significant impact and continuing effect on inflationary expectations, that the election of a Conservative government in 1970 significantly reduced inflationary expectations, that incomes policies are unpredictable in their effect on inflationary expectations and that the effects of all the other variables considered are insignificant.

Carlson and Parkin's next step was to examine the possibility that the six "other variables" considered had the effect of modifying expectations formed via an adaptive scheme rather than influencing inflationary expectations directly. To this end they estimated by OLS the following modified second-order adaptive scheme.

$$p_t^e - p_{t-1}^e = \lambda_0(p_{t-1} - p_{t-1}^e) + \lambda_1(p_{t-2} - p_{t-2}^e) + \sum_{i=1}^{23} \gamma_i x_{it} + v_t \quad (7.26)$$

there being twenty-three variables (most of which are dummies) required to capture the effects of the six variables considered. The estimates of (7.26) are interesting in that the general quality of the estimation is good ( $\bar{R}^2 = 0.75$ ,  $DW = 2.206$ ),  $\lambda_0$  and  $\lambda_1$  are both significant ( $\lambda_0$  at the 1 per cent level and  $\lambda_1$  at 5 per cent)

and all other variables are insignificant at 5 per cent except for the dummy designed to capture the impact effect of the 1967 devaluation which is significant at 1 per cent ( $t$ -ratio = 5.378) and the dummy included to capture the continuing effect of the voluntary price restraint pledged by the Confederation of British Industry, this variable being significant at 5 per cent.

Danes [16] has examined the formation of inflationary expectations in Australia for the period 1967 to 1973 using an observed expectations series based on a quarterly survey conducted by the Australian Chamber of Manufacturers and the Bank of New South Wales.<sup>15</sup> His study is relatively limited, however, in that he considers only the first and second-order versions of each of the adaptive and extrapolative schemes. The possibility that other variables might modify the formation of expectations was not considered by Danes.

Relatively little attention has been given to the possibility of generalizing the form of the expectations-adjustment equation by specifying  $p^e$  as a distributed lag relationship<sup>16</sup> on  $p$  or  $w^e$  as a distributed lag on  $w$ . Turnovsky [131] considered briefly a very limited form of such a relationship.<sup>17</sup> Saunders and Nobay [118] consider a more general specification based on Jorgenson's rational distributed lag function. The form of the expectations formation equation considered by Saunders and Nobay is<sup>18</sup>

15. See above, pp. 105-6.

16. See above, pp. 209-210.

17. See above, pp. 83-88.

18. The notation is a little different from that of Saunders and Nobay.

$$p_t^e = \frac{\phi(L)}{\theta(L)} p_t \quad (7.27)$$

where  $\phi(L) = \phi_0 + \phi_1 L + \phi_2 L^2 + \dots + \phi_{n-1} L^{n-1}$

$$\theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \dots + \theta_n L^n$$

and  $L$  denotes the lag operator.<sup>19</sup> This specification is not empirically viable because an extensive search is required to establish the degree of the polynomials ( $n-1$  and  $n$ ) and because problems of multicollinearity arise in estimation. Accordingly, Saunders and Nobay [118, p. 240] consider the special case of (7.27) in which  $n \rightarrow \infty$  and the weights of both polynomials  $\phi(L)$  and  $\theta(L)$  decline geometrically. That is, the polynomials are assumed to take the following forms.

$$\begin{aligned} \phi(L) &= \lambda + \lambda(1 - \lambda)L + \lambda(1 - \lambda)^2 L^2 + \dots \\ \theta(L) &= 1 + \lambda(1 - \lambda)L + \lambda(1 - \lambda)^2 L^2 + \dots \end{aligned} \quad (7.28)$$

with  $0 < \lambda < 1$ . Note that the same damping factor  $(1 - \lambda)$  applies to both sets of coefficients. Having imposed on the polynomials  $\phi(L)$

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19. A still more general specification could, of course, be obtained by allowing the numbers of terms in  $\phi(L)$  to be unrelated to the number in  $\theta(L)$ .

and  $\theta(L)$  the forms in (7.28), it can be shown<sup>20</sup> that (7.27) is equivalent to

$$p_t^e = \sum_{j=0}^{\infty} \psi_j p_{t-j} \quad (7.29)$$

where  $\psi_j = \lambda(1 - \lambda)^{2j}$ .

Saunders and Nobay actually consider a finite approximation to (7.29) obtained by truncating the right-hand side after the  $n^{\text{th}}$  term. This is unnecessary, however, because the scheme specified in (7.29) is

20. Let  $\psi(L) = \phi(L)/\theta(L)$ , then  $\psi(L)\theta(L) = \phi(L)$  or  
 $(\psi_0 + \psi_1 L + \psi_2 L^2 + \dots)(1 + \theta_1 L + \theta_2 L^2 + \dots) = (\phi_0 + \phi_1 L + \phi_2 L^2 + \dots)$   
 where  $\phi_0 = \lambda$ ,  $\theta_j = \phi_j = \lambda(1 - \lambda)^j$  for  $j = 1, 2, \dots$ . Equating like coefficients of  $L$  produces

$$\psi_0 = \phi_0 = \lambda$$

$$\begin{aligned} \psi_1 + \psi_0 \theta_1 &= \phi_1 \quad \text{i.e. } \psi_1 = \phi_1 - \psi_0 \theta_1 \\ &= \lambda(1 - \lambda) - \lambda \cdot \lambda(1 - \lambda) \\ &= \lambda(1 - \lambda)^2 \end{aligned}$$

$$\begin{aligned} \psi_2 + \psi_1 \theta_1 + \psi_0 \theta_2 &= \phi_2 \\ \text{i.e. } \psi_2 &= \phi_2 - \psi_1 \theta_1 - \psi_0 \theta_2 \\ &= \lambda(1 - \lambda)^2 - \lambda(1 - \lambda)^2 \cdot \lambda(1 - \lambda) - \lambda \cdot \lambda(1 - \lambda)^2 \\ &= \lambda(1 - \lambda)^4 \end{aligned}$$

Continuing in this way we get

$$\psi(L) = \lambda + \lambda(1 - \lambda)^2 L + \lambda(1 - \lambda)^4 L^2 + \dots$$

Hence (7.27) becomes

$$p_t^e = \psi(L)p_t = \lambda p_t + \lambda(1 - \lambda)^2 p_{t-1} + \lambda(1 - \lambda)^4 p_{t-2} + \dots$$

$$\text{or } p_t^e = \sum_{j=0}^{\infty} \psi_j p_{t-j} \quad \text{where } \psi_j = \lambda(1 - \lambda)^{2j}$$

which is (7.29).



viable as it stands. To establish this suppose that the wage equation is

$$w_t = a_0 + a_1 u_t + \delta p_t^e \quad (7.30)$$

Substituting (7.29) for  $p_t^e$  gives

$$w_t = a_0 + a_1 u_t + \delta \lambda p_t + \delta \lambda (1 - \lambda)^2 p_{t-1} + \delta \lambda (1 - \lambda)^4 p_{t-2} + \dots$$

The Koyck transformation can then be applied to reduce this to<sup>21</sup>

$$w_t = a_0 \lambda (2 - \lambda) + a_1 u_t - a_1 (1 - \lambda)^2 u_{t-1} + \delta \lambda p_t + (1 - \lambda)^2 w_{t-1}$$

which is a reduced form equation exhibiting the same features as those considered in Chapter Four.<sup>22</sup> Hence the expectations formation scheme specified in (7.29) is a viable one from the point of view of estimation.

While Saunders and Nobay's basic suggestion that the expectations-formation equation be specified as a rational distributed lag is a useful one, the assumptions they impose to arrive at an empirically viable form (viz (7.29) truncated after a finite number of terms) are sufficiently restrictive as to seriously undermine the usefulness of the scheme. In fact, by comparing (7.29) with (7.23) it is clear that Saunders and Nobay's final scheme closely resembles the adaptive scheme. There are two main points of difference. Firstly the damping factor is  $(1 - \lambda)^2$  in (7.29) while it is  $(1 - \gamma)$

21. Compare with equation (1.12) of Saunders and Nobay [118, p. 241].

22. See above, pp. 114-5.

in (7.23), the distributed lag representation of the adaptive scheme. The effect is to make the sum of the weights on  $p_t, p_{t-1}, \dots$  in (7.29) equal to  $1/(2 - \lambda)$  which is less than unity for  $0 < \lambda < 1$ . As was shown above<sup>23</sup> in the case of the adaptive scheme this sum of weights is unity regardless of the value of the damping factor. Saunders and Nobay in fact set out to specify an expectations formation scheme in which the weights on  $p_t, p_{t-1}, \dots$  sum to less than unity.<sup>24</sup> An unfortunate consequence of such an expectations formation scheme is that in the steady state (when  $p_t = p_{t-1} = \dots = \bar{p}$ ) inflation can not be fully anticipated (because  $\bar{p}^e = \bar{p} \sum_{j=0}^{\infty} \psi_j$  from (7.29) and hence  $\bar{p}^e < \bar{p}$ ). The second difference between (7.23) and (7.29) is that the current rate of inflation appears in (7.29) while in (7.23) the most recent inflation rate influencing inflationary expectations formed in period  $t$  is that of period  $(t-1)$ . This feature is a deficiency of (7.29). It is implausible that expectations could be formed on the basis of information which is not available. If this aspect of (7.29) were to be considered plausible it is necessary that the inflationary expectation be formed in the instant of time at which period  $t$  ends, this being the earliest point in time at which  $p_t$  could be known. This criticism does not apply to (7.23) because a full period (namely  $t$ ) is available for the formation of the inflationary expectation, the most recent information used being that available at the end

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23. See p. 210n.

24. See [118, p. 239]. Their reason for doing so was to meet the assertion of Sargent [116] that schemes in which the weights sum to unity bias downward the coefficient  $\delta$  in the wage equation. See above, p. 108.

of period  $(t-1)$ . The criticism that (7.29) includes the current rate of inflation can be removed by modifying the basic expectations formation scheme (7.27) by replacing  $p_t$  with  $p_{t-1}$ . While the basic suggestion of Saunders and Nobay that inflationary expectations be specified as a rational distributed lag of the actual rate of inflation is a useful one, their implementation of this suggestion is seriously inadequate.

Parkin [91] suggests a model which allows the expected rate of wage-inflation to be decomposed into "... constituent price and productivity [expectations]". [91, p. 131] While Parkin's study suffers from a number of quite serious shortcomings<sup>25</sup> this particular aspect is worthy of consideration here. Parkin's point of departure is the assumption that labour produces a non-internationally traded good and an internationally traded good whose prices are  $P$  and  $\Pi$  respectively. The implied excess demand for labour function is<sup>26</sup>

$$x = g\left(\frac{W}{P}, \frac{\Pi}{P}, Q\right) \quad (7.31)$$

where  $W$  denotes the earnings rate and  $Q$  the productivity of labour. Differentiation of (7.31) with respect to time produces

$$\frac{dx}{dt} = g_1 \frac{dW/P}{dt} + g_2 \frac{d\Pi/P}{dt} + g_3 \frac{dQ}{dt}$$

where  $g_1$  denotes the partial derivative of  $g$  with respect to the 1<sup>th</sup>

25. See Challen and Hagger [13] and Neville [83] for a discussion of these deficiencies. Parkin's reply to Neville is [94].

26. The notation is Parkin's for the time being. In what follows, a number of errors in Parkin's derivation have been corrected.

argument. Then,

$$\frac{dx}{dt} = g_1 \left[ \frac{P \frac{dW}{dt} - W \frac{dP}{dt}}{P^2} \right] + g_2 \left[ \frac{P \frac{d\Pi}{dt} - \Pi \frac{dP}{dt}}{P^2} \right] + g_3 Q \dot{q}$$

where  $\dot{q}$  denotes  $\frac{dQ}{dt}/Q$ , the proportional rate of change of  $Q$ .

Continuing,

$$\begin{aligned} \frac{dx}{dt} &= g_1 \frac{1}{P} \frac{dW}{dt} - g_1 \frac{W}{P^2} \frac{dP}{dt} + g_2 \frac{1}{P} \frac{d\Pi}{dt} - g_2 \frac{\Pi}{P^2} \frac{dP}{dt} + g_3 Q \dot{q} \\ &= g_1 \frac{W}{P} \dot{w} + g_2 \frac{\Pi}{P} \dot{\pi} - (g_1 \frac{W}{P} + g_2 \frac{\Pi}{P}) \dot{P} + g_3 Q \dot{q} \end{aligned}$$

where  $\dot{w}$  and  $\dot{\pi}$  denote the proportional rate of change of  $W$  and  $\Pi$  respectively. If the labour market is in equilibrium, it follows that

$$g_1^* \dot{w} + g_2^* \dot{\pi} - (g_1^* + g_2^*) \dot{P} + g_3^* \dot{q} = 0$$

where  $g_1^* = g_1 \frac{W}{P}$ ,  $g_2^* = g_2 \frac{\Pi}{P}$  and  $g_3^* = g_3 Q$ . Rearranging,

$$\dot{w} = -\frac{g_2^*}{g_1^*} \dot{\pi} + \left( \frac{g_1^* + g_2^*}{g_1^*} \right) \dot{P} - \frac{g_3^*}{g_1^*} \dot{q} \quad (7.32)$$

If relative shares are constant<sup>27</sup> then  $g_3^* = -g_1^*$  and (7.32) reduces to

27. The requirement for constant relative shares is that profit margins are constant in the production of both tradeable and non-traded goods. That is,

$$\dot{P} = \dot{\pi} = \dot{w} - \dot{q}$$

Substitution in (7.32) yields

$$\dot{\pi} + \dot{q} = -\frac{g_2^*}{g_1^*} \dot{\pi} + \left( 1 + \frac{g_2^*}{g_1^*} \right) \dot{\pi} - \frac{g_3^*}{g_1^*} \dot{q}$$

$$\text{i.e.} \quad \dot{\pi} + \dot{q} = \dot{\pi} - \frac{g_3^*}{g_1^*} \dot{q}$$

$$\text{or} \quad \dot{q} = -\frac{g_3^*}{g_1^*} \dot{q}$$

which implies that  $g_3^* = -g_1^*$  as asserted.

$$\dot{w} = h\dot{\pi} + (1 - h)\dot{p} + \dot{q} \quad (7.33)$$

where  $h = -g_2^*/g_1^*$  and it is expected that  $0 < h < 1$ . If expectations about  $\dot{w}$  are assumed to be rational,<sup>28</sup> it follows immediately that

$$\dot{w}^e = h\dot{\pi}^e + (1 - h)\dot{p}^e + \dot{q}^e \quad (7.34)$$

where as usual the  $e$  superscript denotes the expectation of the variable in question. (7.34) provides an explicit basis for decomposing the expected rate of wage inflation into a linear combination of the expected rate of inflation of tradeables, the expected rate of inflation of domestic non-traded goods and the expected rate of change of productivity. It is then necessary to set up subsidiary hypotheses about the formation of  $\dot{\pi}^e$ ,  $\dot{p}^e$  and  $\dot{q}^e$ . In doing so it is important that the steady state property  $\bar{w} = \bar{w}^e$  be preserved. This point has been argued by Challen and Hagger [13]. The approach Parkin adopts fails in this regard and will therefore not be considered here.<sup>29</sup> Recasting (7.34) in terms of more standard notation produces

$$w_t^e = h\pi_t^e + (1 - h)p_t^e + q_t^e \quad (7.35)$$

in which case one plausible set of subsidiary hypotheses is

28. Parkin makes no explicit mention of rational expectations in Muth's [81] sense. This is, however, the effect of his assumption that "... expectations about  $\dot{w}$  are formed in a manner compatible with expectations about  $\pi$ ,  $p$  and  $q$ ..." [91, p. 132]

29. See however Parkin [91, pp. 132-3].

$$\pi_t^e - \pi_{t-1}^e = \eta_1(\pi_{t-1} - \pi_{t-1}^e) + \eta_2 Z_{1t} \quad (7.36)$$

$$p_t^e - p_{t-1}^e = \gamma_1(p_{t-1} - p_{t-1}^e) + \gamma_2 Z_{2t} \quad (7.37)$$

$$q_t^e = q_{t-1} \quad (7.38)$$

where  $Z_{1t}$  summarizes non-domestic influences on the expected rate of tradeables, the most important of which are likely to be the exchange rate and the rate of overseas inflation, and  $Z_{2t}$  summarizes domestic influences on the expected rate of inflation of domestic non-traded goods such as government policy and important wage bargains which are well-publicized like those applicable to the Metal Trades Unions.

Relationships (7.36) and (7.37) are quite straightforward; they are first-order adaptive schemes in which the formation of expectations is modified by influences other than the variable about which the expectation is being formed. The rationale for (7.38) is that the rate of growth of productivity has been fairly constant over time and it is therefore likely that expectations about it will be formed on the basis of a very simple extrapolative scheme. In the steady state,  $\pi_t = \pi_{t-1} = \dots = \bar{\pi}$ ,  $p_t = p_{t-1} = \dots = \bar{p}$ ,  $q_t = q_{t-1} = \dots = \bar{q}$  and  $Z_{1t} = Z_{2t} = 0$ . Hence from (7.36),<sup>30</sup>  $\pi_t^e = \pi_{t-1}^e = \dots = \bar{\pi}^e = \bar{\pi}$ , from (7.37)  $p_t^e = p_{t-1}^e = \dots = \bar{p}^e = \bar{p}$  and from (7.38)  $q_t^e = q_{t-1}^e = \dots = \bar{q}^e = \bar{q}$ . Then, from (7.35), in the steady state,

30. (7.36) with  $Z_{1t} = 0$  is equivalent to

$$\pi_t^e = \gamma_1 \pi_{t-1} + \gamma_1(1 - \gamma_1) \pi_{t-2} + \gamma_1(1 - \gamma_1)^2 \pi_{t-3} \dots$$

See (7.23) on p. above. In the steady state,  $\pi_{t-1} = \pi_{t-2} = \dots = \bar{\pi}$  and it follows that  $\pi_t^e = (\gamma_1 + \gamma_1(1 - \gamma_1) + \dots) \bar{\pi} = \bar{\pi}$  since  $0 < \gamma_1 < 1$ .

$$\begin{aligned}
 w_t^e &= h\bar{\pi} + (1 - h)\bar{p} + \bar{q} \\
 &= \bar{w}^e
 \end{aligned}
 \tag{7.39}$$

In current and standard notation (7.33) is

$$w_t = h\pi_t + (1 - h)p_t + q_t \tag{7.40}$$

which in the steady state reads

$$\bar{w} = h\bar{\pi} + (1 - h)\bar{p} + \bar{q} \tag{7.41}$$

The left-hand sides of (7.39) and (7.41) are identical which establishes that  $\bar{w}^e = \bar{w}$  or that (7.35) and the subsidiary hypotheses (7.36), (7.37) and (7.38) are consistent with fully anticipated wage inflation in the steady state as long as expectations about  $w$  (previously  $\dot{w}$ ) are indeed rational as was assumed in the formulation of (7.34).

### 7.5 Suggestions for Further Work

A considerable number of modifications and extensions of the prototype models have been considered in the preceding sections of this chapter. It is appropriate now to attempt to put this discussion into perspective by identifying those modifications and extensions most likely to be fruitful in the context of the Australian economy. The modifications and extensions of the prototype models highlighted in this way can then be looked upon as suggestions for further work on the expectations hypothesis with reference to the Australian economy.

There are three main features of the Australian economy which are crucial for the specification of an expectational model but which are not taken into account in the specification of the prototype models. The first and perhaps most important feature is that the Australian economy is an open one and, as such, explicit account needs to be taken of certain non-domestic influences in modelling the inflationary process for the Australian economy. This being the case it is appropriate to consider an expectational model in the spirit of Parkin, Sumner and Ward [97], to consider decomposition of expectations along the lines of Parkin [91] and to consider expectations-formation schemes in which expectations are modified by such variables as overseas rates of inflation and the exchange rate.

The second feature of the Australian economy which is important for the specification of an expectational model is the institutional structure of the wage bargaining process. Of particular importance are the influence of "flow-ons" from awards made to wage leaders such as the Metal Trades Unions, and the effect of the National Wage Judgement brought down at roughly annual intervals by the Full Bench of the Australian Conciliation and Arbitration Commission. The literature considered in the earlier sections of this chapter is of less help here although a useful line to pursue is that suggested by Carlson and Parkin [11] in which influences of these types are allowed to modify the formation of expectations. Variables worthy of consideration in this context are award wages and sets of dummy variables to capture the impact and continuing effects of bargains made by wage leaders and the bringing down of the National Wage Judgement.



The third feature of the Australian economy relevant to the specification of an expectational model is the extensive system of indirect taxation. Here again a model in the spirit of Parkin, Sumner and Ward [97] is worthy of consideration.

In addition to the above suggestions based on certain features of the Australian economy, some empirical experimentation may also be fruitful. In particular, consideration needs to be given to lags in the response of the rate of wage-inflation to changes in the excess demand for labour and to expectations-formation schemes which are either of higher orders or are specified more generally than those considered in the context of the prototype models.

### Appendix I: Notation

E	Employment
EDL I	Hagger-Rayner [42] excess demand for labour index
EDL II	
L	Labour force
p	Percentage rate of change of prices (inflation rate)
P	Index of prices
p <sup>e</sup>	Expected percentage rate of change of prices (expected inflation rate)
q	Percentage rate of change of output per man
u	Unemployment rate (per cent)
U	Unemployment (persons)
w	Percentage rate of change of money wage costs per man (rate of wage-inflation)
W	Index of money wage costs per man
w <sup>e</sup>	Expected percentage rate of change of money wage costs per man (expected rate of wage-inflation)
y	Ratio of constant price GDP to its full employment level
Y	Constant price gross domestic product
Y*	Full employment level of constant price GDP

## Appendix II: Sources of Data

- E        Civilian Employees, Persons: Australia excluding Defence Forces, Australian Bureau of Statistics, *Employment and Unemployment*, Reference No. 6.4.
- EDL I    Excess Demand for Labour, Australia, Seasonally Adjusted,
- EDL II   Hagger and Rayner [42], Table V, p. 179.
- P        Consumer Price Index, All Groups, Six Capitals, ABS, *Consumer Price Index*, Reference No. 9.1.
- U        Registered Unemployed excluding school leavers, ABS, *Employment and Unemployment*, Reference No. 6.4.
- W        Average Weekly Earnings per Employed Male Unit, ABS, *Wage Rates and Earnings*, Reference No. 6.16.
- Y        Gross Domestic Product at Average 1966-67 Prices, Seasonally Adjusted, ABS, *Quarterly Estimates of National Income and Expenditure*, Reference No. 7.10.

All series were quarterly. Where the published source data is monthly, last-month-of-the-quarter observations were taken. Seasonally unadjusted data was used except where the contrary is stated.

The sample periods used were as follows.

For E, P, U and W:        1958(3) - 1974(4), 66 observations

For EDL I and EDL II:    1958(3) - 1972(1), 55 observations

For Y:                    1961(4) - 1974(4), 53 observations.

These sample periods are those *actually* used in the estimations reported in Chapter Six, that is, after making allowance for the lagged values required for some variables.

### Appendix III: Data Listing

The following is a listing of the *original* time series required for the construction of the data used in the empirical work reported in Chapter Six. The calculation from these original time series of the variables actually used in the estimations reported in Chapter Six is described in Chapter Five. The sources of the original time series are given in Appendix II.

The periods for which the original time series are given here are longer than the sample periods referred to in Appendix II to allow for the wastage of observations resulting from the calculation of rates of change, the alignment of the "level" variables (e.g. u, EDL I) by means of a four-quarter moving average and the requirement for lagged values of some variables.

Details of the units in which the original time series are given are as follows.

E	Thousands of persons
EDL I	
	Per cent of employment
EDL II	
P	Index, Base: Year 1966-67 = 100.0
U	Thousands of persons
W	Dollars
Y	Million dollars.

Quarter	E	EDL I	EDL II	P	U	W	Y
1956(1)	2782.3	3.05	3.81	77.0	29.7	33.62	
(2)	2854.8	2.24	2.44	79.4	31.0	36.04	
(3)	2777.1	1.51	1.69	81.4	33.2	36.24	
(4)	2861.9	1.33	1.38	81.4	33.8	38.26	
1957(1)	2875.1	1.10	1.16	81.2	44.5	35.34	
(2)	2864.9	0.60	0.72	81.9	51.0	37.56	
(3)	2862.6	0.34	0.40	82.1	47.6	38.92	
(4)	2871.0	0.23	0.26	81.9	53.6	41.18	
1958(1)	2944.2	0.16	0.18	82.4	61.0	37.36	
(2)	2942.2	-0.10	-0.04	82.7	65.1	39.86	
(3)	2953.1	-0.14	-0.13	82.8	58.5	40.32	
(4)	2974.0	-0.03	-0.06	83.5	56.4	42.70	
1959(1)	3001.2	-0.01	-0.01	83.8	64.1	38.28	
(2)	3004.7	-0.09	-0.07	84.2	63.2	40.88	
(3)	3031.9	0.09	0.05	84.5	50.3	42.30	
(4)	3060.5	0.31	0.25	85.0	48.5	44.56	4044
1960(1)	3109.8	0.61	0.54	85.8	50.1	41.88	4130
(2)	3126.5	0.81	0.76	87.3	45.3	45.32	4177
(3)	3158.1	1.28	1.16	88.3	34.2	45.36	4306
(4)	3191.0	0.96	1.04	88.9	40.4	47.74	4229
1961(1)	3179.2	0.11	0.32	89.5	75.8	43.62	4189
(2)	3133.2	-1.09	-0.79	90.1	107.7	46.30	4170
(3)	3122.1	-1.64	-1.50	89.9	105.6	46.70	4150
(4)	3157.0	-1.43	-1.48	89.6	93.0	49.20	4191
1962(1)	3204.1	-0.87	-1.01	89.4	89.5	45.70	4340
(2)	3213.5	-0.77	-0.79	89.4	87.2	48.80	4432
(3)	3232.2	-0.56	-0.62	89.6	71.5	47.90	4480
(4)	3258.0	-0.64	-0.62	89.7	74.1	50.50	4542
1963(1)	3304.1	-0.28	-0.37	89.7	73.5	46.90	4573
(2)	3314.8	-0.26	-0.27	90.0	76.5	50.30	4625
(3)	3341.6	0.05	-0.02	90.2	55.5	49.80	4765
(4)	3386.2	0.21	0.17	90.1	53.5	54.10	4900
1964(1)	3442.7	0.61	0.51	90.7	49.4	49.10	4826
(2)	3460.7	1.15	1.02	91.5	45.4	52.80	4972
(3)	3489.6	1.83	1.66	92.6	33.1	54.10	5095
(4)	3534.8	1.52	1.60	93.7	35.6	57.50	5200
1965(1)	3592.9	1.83	1.75	94.3	37.3	53.00	5226
(2)	3604.1	2.08	2.02	95.2	40.4	56.60	5340
(3)	3619.3	2.22	2.18	96.2	34.2	57.60	5308
(4)	3652.5	1.16	1.43	97.4	44.9	59.60	5265
1966(1)	3701.3	0.98	1.03	97.6	52.7	55.50	5284
(2)	3803.5	1.00	0.99	98.4	56.9	58.70	5349
(3)	3816.4	0.96	0.97	98.8	49.2	60.90	5503
(4)	3867.6	0.57	0.67	99.7	53.3	63.10	5560
1967(1)	3894.7	0.67	0.64	100.1	58.4	59.30	5718
(2)	3902.3	0.63	0.64	101.3	66.2	63.50	5763
(3)	3921.5	0.75	0.72	102.7	51.4	64.20	5715
(4)	3976.1	0.50	0.57	103.0	55.4	66.90	5785
1968(1)	4014.9	0.58	0.56	103.4	61.5	63.10	5911
(2)	4029.8	0.80	0.75	104.2	62.7	67.10	5991
(3)	4053.2	1.25	1.14	104.6	46.6	67.60	6200
(4)	4115.4	0.79	0.90	105.7	53.8	72.30	6365

Quarter	E	EDL I	EDL II	P	U	W	Y
1969(1)	4146.4	1.05	0.98	106.4	53.4	68.30	6403
(2)	4171.7	1.45	1.35	107.2	52.8	72.60	6515
(3)	4202.2	2.10	1.94	107.8	39.5	73.90	6619
(4)	4282.9	1.19	1.42	108.7	45.1	78.70	6726
1970(1)	4320.9	1.75	1.61	109.8	44.2	72.50	6681
(2)	4340.4	2.13	2.03	111.2	49.9	79.10	6898
(3)	4366.9	1.95	1.99	111.9	46.0	80.70	6940
(4)	4449.6	1.05	1.27	114.0	47.6	86.10	6959
1971(1)	4479.0	1.20	1.16	115.2	59.3	81.80	7124
(2)	4477.8	1.22	1.22	117.2	64.0	89.50	7105
(3)	4460.1	1.04	1.08	119.4	61.4	90.00	7291
(4)	4492.1	0.11	0.34	122.2	74.5	96.00	7311
1972(1)	4502.9	0.08	0.09	123.4	88.5	89.20	7262
(2)	4507.0			124.5	95.8	96.70	7376
(3)	4512.6			126.2	85.4	96.80	7412
(4)	4579.5			127.7	83.0	104.10	7599
1973(1)	4635.8			130.4	75.4	97.20	7770
(2)	4654.3			134.7	77.9	107.80	7854
(3)	4701.0			139.6	60.8	110.20	8049
(4)	4795.4			144.6	69.9	119.90	8064
1974(1)	4845.3			148.1	74.1	113.30	8182
(2)	4873.5			154.1	75.4	128.50	8068
(3)	4835.5			162.0	117.7	137.90	7750
(4)	4788.5			168.1	220.4	154.20	7984

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